

***Astragalus ripleyi* Barneby (Ripley's milkvetch):
A Technical Conservation Assessment**



**Prepared for the USDA Forest Service,
Rocky Mountain Region,
Species Conservation Project**

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COVER PHOTO CREDIT

Astragalus ripleyi (Ripley's milkvetch). Photo taken by Teresa Prendusi.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *ASTRAGALUS RIPLEYI*

Status

Astragalus ripleyi (Ripley's milkvetch) is designated a sensitive species by both the USDA Forest Service and the Bureau of Land Management (BLM). The NatureServe Global Rank for this species is vulnerable (G3). It is designated imperiled (S2) by the Colorado Natural Heritage Program and vulnerable (S3?) by the New Mexico Natural Heritage Program. The question mark denotes some uncertainty with respect to the species status. This uncertainty is likely because observed abundance of *A. ripleyi* within its range indicates a vulnerable (S3) status, but its narrow range and incomplete information on its historical abundance suggest the species may warrant a rating of imperiled (S2).

Primary Threats

Astragalus ripleyi appears inherently vulnerable to herbivores, as it is palatable to insects, a diversity of wildlife species, and livestock. Sheep grazing may be particularly harmful. Light to moderate use by livestock and wildlife does not seem unduly detrimental, especially if a seasonal-rotational system for livestock is practiced. Although *A. ripleyi* does not colonize newly disturbed sites, its apparent requirement for relatively open environments suggests that it benefits from some disturbance and that complete fire suppression may be detrimental to the long-term sustainability of the species. However, significant soil disturbance and progressive soil erosion are likely very detrimental because its long-lived root system appears to be the mechanism by which populations survive. Active and severe soil erosion currently threatens at least one occurrence. Weed infestation has been cited as a threat to *A. ripleyi*, and *Melilotus officinalis* (sweet yellow clover) that has been sown to revegetate land may be particularly detrimental. *Astragalus ripleyi* is a substrate endemic, being restricted to soils derived from volcanic formations. Its limited geographic range indicates that it is vulnerable to permanent habitat modification, such as development and urbanization.

Primary Conservation Elements, Management Implications and Considerations

There are few formal, written management plans directly concerning *Astragalus ripleyi*, and the management of each area in which it occurs deals with the species in a different manner. There is a dearth of information concerning its biology and optimal management procedures, but the current information available suggests that the species is likely to survive satisfactorily if more research is carried out and some basic management strategies are followed. The following management practices would benefit the species: a rest rotation system for moderate cattle grazing intensity, maintaining some areas with populations of *A. ripleyi* primarily for elk winter range, minimizing off-road vehicle traffic in occupied and potential habitat, and performing logging and wood-cutting activities only during winter. Long-term fire suppression appears to have influenced the distribution and abundance of this species, as mature canopy cover appears to exclude *A. ripleyi*. The degree to which long-term fire suppression has adversely impacted the range and abundance of this species largely depends upon the longevity of the root systems, the frequency of seedling recruitment, and seed dispersal pattern. Current evidence suggests seedling recruitment is infrequent and seeds have a restricted dispersal pattern. Both of these characteristics make the species more vulnerable to the consequences of fire suppression. One important reason to continue monitoring and studying this regional endemic species is its apparent resilience to many land use practices. If population trends begin to show a steady decline or contraction of range over several years, it may indicate that a fundamental problem is occurring with the ecology of a particular region. This long-lived perennial may be a "barometer" of changes in the ecosystem. Although it cannot be determined how its abundance and range have been affected over the last century, with the current understanding of its ecology and biology on which to build, it may be a valuable species to monitor in the future.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the USDA Forest Service (USFS) Rocky Mountain Region (Region 2). *Astragalus ripleyi* (Ripley's milkvetch) is the focus of an assessment, because it is a sensitive species in both Regions 2 and 3 of the USFS. Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or in habitat capability that would reduce its distribution (FSM 2670.5 (19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical.

This assessment addresses the biology of *Astragalus ripleyi* throughout its range in Region 2 and Region 3. The broad nature of the assessment leads to some constraints on the specificity of information for particular locales. This introduction defines the goal of the assessment, outlines its scope, and describes the process used in its production.

Goal of Assessment

Species conservation assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of the broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations but provides the ecological background upon which management must be based. However, it does focus on the consequences of changes in the environment that result from management (that is management implications). Furthermore, it cites management recommendations proposed elsewhere and, when management recommendations have been implemented, the assessment examines the success of the implementation.

Scope of Assessment

This *Astragalus ripleyi* assessment examines the biology, ecology, conservation status, and management of this species with specific reference to the geographic and ecological characteristics of the Rocky Mountain

Region. Although some of the literature relevant to this species originates from field investigations outside the region, this document places that literature in the ecological and social contexts of the central Rocky Mountains. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *A. ripleyi* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting this synthesis but placed in a current context.

In producing this assessment, the refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies were reviewed. The assessment emphasizes the refereed literature, because this is the accepted standard in science. Some non-refereed literature was used in the assessment because information was unavailable elsewhere, but it is regarded with greater skepticism. Many reports or non-refereed publications on rare plants are often 'works-in-progress' or isolated observations on phenology or reproductive biology. For example, demographic data may have been obtained during only one year when monitoring plots were first established. Insufficient funding or manpower may have then prevented work in subsequent years. One year of data is generally considered inadequate for publication in a refereed journal but still provides a valuable contribution to the knowledge base of a rare plant species. Unpublished data (e.g. Natural Heritage Program and herbarium records) were important in estimating the geographic distribution and population sizes. These data require special attention because of the diversity of persons and methods used in collection. Records that were associated with locations at which herbarium specimens had been collected at some point in time were weighted higher than observations only.

Treatment of Uncertainty

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science includes approaches for dealing with uncertainty. A commonly accepted approach to science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct critical experiments in the ecological sciences, and often observations, inference, good thinking, and models must be relied on to guide the understanding of ecological relations.

In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate. While well-executed experiments represent the strongest approach to developing knowledge, alternative approaches (modeling, critical assessment of observations, and inference) are accepted approaches to understanding features of biology.

Publication of the Assessment on the World Wide Web

To facilitate use of species assessments in the Species Conservation Project, they are being published on the Region 2 World Wide Web site. Placing the documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More important, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review

Assessments developed for the Species Conservation Project have been peer reviewed prior to release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing at least two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

In 1990, the U.S. Fish and Wildlife Service (USFWS) nominated *Astragalus ripleyi* as a Category 2 candidate for listing as threatened or endangered. Category 2 candidates were “taxa for which information in the possession of the Service indicated that proposing to list as endangered or threatened was possibly appropriate, but for which sufficient data on biological vulnerability and threat were not currently available to support proposed rules” (U.S. Fish and Wildlife Service 1996). In 1996 the U.S. Fish and Wildlife Service discontinued the use of Category 2 as a species designation, and there are no current plans to list *A. ripleyi* (U.S. Fish and Wildlife Service 1996).

Astragalus ripleyi is designated sensitive by both the USFS (U.S. Forest Service 2003) and the Bureau of Land Management (Colorado Bureau of Land Management 2000). The NatureServe Global Rank¹ is vulnerable (G3), and the National Heritage Status Rank is also vulnerable (N3) (NatureServe 2002). *Astragalus ripleyi* is designated imperiled (S2) by the Colorado Natural Heritage Program and vulnerable (S3?) by the New Mexico Natural Heritage Program. The question mark denotes some uncertainty with respect to the species status. This uncertainty is likely because observed abundance of *A. ripleyi* within its range indicates a vulnerable (S3) status, but its narrow range and incomplete information on its historical abundance suggest the species may warrant a rating of imperiled (S2). It is designated a protected species by The Colorado Natural Areas Program (Colorado Natural Areas Program 2002). The State of New Mexico ranks it with R-E-D code of “1-2-2”, indicating that it is rare in both New Mexico and Colorado and endangered in a portion of its range but that the potential for its extinction is low in the foreseeable future (Sivinski and Lightfoot 1995). In New Mexico, *A. ripleyi* was listed State Endangered under Section 1, Section 9-10-10 NMSA 1978, Plant Endangered Species Act NRD 85-3. It was subsequently downlisted to Sensitive in 1991 (Sivinski and Lightfoot 1992), under Section 1, Section 9-10-10 NMSA 1998, Plant Endangered Species Act, as revised, NMFRCD Rule No. 91-1, December, 1991.

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

There are few formal management plans that directly address *Astragalus ripleyi*. Currently management of the species appears essentially subject to the individual land manager’s personal knowledge, and the continuity of management strategy (for example during staff turnover) is not assured.

“The Revised Land and Resource Management Plan for the Rio Grande National Forest” (USDA Forest Service 1996) mentions general considerations applicable to all “species listed as TES or Colorado Natural Heritage Program Species of Concern” and created a “Special Interest Area” for *Astragalus ripleyi*. An amendment was made to this plan in 1999 (USDA Forest Service 1999). Mitigation recommendations were to “avoid timber harvest and prescribed fire in

¹For definitions of G and S ranking see Rank in the Definition section at the end of this document.

potential *A. ripleyi* [Ripley milkvetch] habitat” (that is, open ponderosa pine/Arizona fescue stands with some Douglas fir where canopy coverage by trees is less than 25 percent) and “keep timber harvest and prescribed fire above the 9,200 feet contour line in the Analysis Area to protect *A. ripleyi*.” Surveys for *A. ripleyi* are conducted throughout the Rio Grande National Forest in Region 2 when appropriate, such as prior to activities that will cause disturbance. A sensitive plant guide was developed for Rio Grande National Forest to assist field crews in recognizing *A. ripleyi* (Erhard 1994). In addition, some reproductive biology research and monitoring studies were carried out on the Rio Grande National Forest in the late 1990s (Coles 1996, Burt 1997, 1998, 1999). Based on the results of these studies, the Forest has decided to end intensive monitoring of this species (USDA Forest Service 2002).

In 1989, the Carson National Forest in USFS Region 3 issued an appendix, “Implementation Plan for the Management of *Astragalus ripleyi* on the Carson National Forest”, to a parent inventory document, “An inventory of *Astragalus ripleyi* on the Carson National Forest” (Braun 1988). This Implementation Plan required surveys to be made on the Tres Piedras and Questa districts, where the species is known to occur, before any activities on occurrence sites were carried out. The plan directed that monitoring studies of known sites were to be undertaken yearly and that all surveys were to be conducted during flowering and fruiting periods. Surveys and monitoring studies were made in 1991 and 1992 but only sporadically since then (Long personal communication 2002, Romero personal communication 2002). As a general rule, USFS land managers seek to avoid known populations during development activities (Erhard personal communication 2002, Long personal communication 2002). On one of the ranger districts of the Carson National Forest, New Mexico, a mitigation recommendation after disturbance projects is that no seed of aggressive species, particularly *Melilotus officinalis* and *Trifolium repens* (white clover) be allowed to be planted on or within windblow distance of known *A. ripleyi* sites (Long personal communication 2002).

A draft of the Bureau of Land Management San Luis Resource Management Plan (Bureau of Land Management 1989) mentioned that *Astragalus ripleyi* occurred within the resource area but made no specific management recommendations. Few monitoring or survey activities occur on the La Jara Resource District, but plans for development projects consider *A. ripleyi* if the species is known from past inventories to exist within the development area (Cassell personal communication

2002). In 1991, the San Luis Resource Management Plan was approved, designating the Ra Jadero Canyon in Conejos County, Colorado as an Area of Critical Environmental Concern (ACEC). Primarily due to the presence of the population of *A. ripleyi*, the area was also designated a Colorado Natural Area in 1996 (Colorado Natural Areas Program 2002). An ACEC designation gives BLM authority to provide special management to unique species or other significant natural resources. At the present time there are no formal management protocols or plans specifically for *A. ripleyi*. Mechanized vehicle traffic is limited by season and also restricted to designated roads and trails within the ACEC (Bureau of Land Management 1991). Ra Jadero Canyon ACEC is currently managed by the La Jara Resource Area, which was formerly part of the San Luis Resource Area. An adjacent tract of land owned by the State Land Board has been placed under a Stewardship Trust and also designated a Colorado Natural Area by the Colorado Natural Areas Program partly because of the known populations of *A. ripleyi* (Page personal communication 2002, Colorado Natural Areas Program undated). Some protection is also afforded this species in this area. For example, logging activities are restricted to winter months to minimize soil disturbance. The Colorado Natural Areas Program has appointed a steward for the land in Ra Jadero Canyon that has been designated a Colorado Natural Area, and periodically the sites within the Natural Area are surveyed for *A. ripleyi* (Karges personal communication 2002).

The Colorado Division of Wildlife does not have a management plan for either of the areas where *Astragalus ripleyi* occurs on its property, and it does not currently consider the species when managing those areas (Navo personal communication 2002). However, it is anticipated that a management plan will be written within the next few years for one area that currently, and in the foreseeable future, provides winter range for elk and deer but does not permit livestock grazing. *Astragalus ripleyi* is likely to be considered in this management plan. It is unlikely that *A. ripleyi* is significantly impacted under present management practices, as this area primarily provides winter forage for elk.

Biology and Ecology

Classification and description

Systematics and synonymy

The genus *Astragalus* belongs to the Fabaceae or Leguminosae family, commonly known as the pea

family. Members of the genus *Astragalus* are known from North and South America, Europe, Asia, India, and Africa (Barneby 1964). North America is particularly rich in *Astragalus* species. It is an extremely variable genus both in morphology and habitat requirements. *Astragalus ripleyi* belongs to the Lonchocarpus section and Homoloboid phalanx of the genus *Astragalus* (Barneby 1964). Taxonomically, it is closely related to *A. schmolliae*, a regional endemic in the Mesa Verde area of southwestern Colorado. Both species are local and somewhat taxonomically isolated. The dorsiventrally compressed pod of *A. schmolliae* is very similar to that of *A. lonchocarpus*, and the relationship of *A. ripleyi* to Lonchocarpus can be most easily understood through its likeness to *A. schmolliae*. Superficially it would be possible to refer *A. ripleyi* to section Collini even though it lacks some definitive characters, such as the basal pouch characteristic of the calyx, of this section (Barneby 1964). Many members of the Lonchocarpus section are endemic to relatively narrow ranges (Barneby 1964). However, *A. lonchocarpus* is a common and widespread member of the section and is, to some extent, sympatric with *A. ripleyi*.

History of species

In 1935, *Astragalus ripleyi* was first collected in Colorado by Francis Ramaley and K. R. Johnson in "Conejos Canyon", but it was not described until two decades later (specimen at University of Colorado Herbarium). In New Mexico, *A. ripleyi* was first discovered in 1947 in Taos County about 2 miles south of Questa (Barneby 1952). The species was formally described by Rupert Barneby (1952) and named after his friend and collaborator H. Dwight Ripley who had collected it and first recognized it as new to science.

Non-technical description

Astragalus ripleyi is an erect herbaceous perennial with stems from 40 to 100 cm (16 to 36 inches) tall (**Figure 1**). The stems arise from a subterranean crown (Barneby 1952, Isely 1998). The stems branch prolifically above a simple tubular-shaped (fistular) base. The root system has been described as rhizomatous (Barneby 1952, Isely 1998). Even though stems from the same plant may be 10 cm away from each other, Burt (1997) concluded that there was no evidence of a truly rhizomatous root system. *Astragalus ripleyi* has 13 to 19 narrow linear-oblong, somewhat folded leaflets that are hairless (glabrous) on the upper surface. The herbage otherwise has flat-laying hairs (appressed pubescence). The nodding flowers are lemon-yellow, and the large, blade-like pods are pendulous with

conspicuously long stipes (**Figure 2**; Barneby 1952, Martin and Hutchins 1980). Stipes refers to the stalks between the pod body and the calyx.

Within its range, *Astragalus ripleyi* is recognizable by its robust habit, the pale yellow reflexed flowers, and especially the pendulous, exerted flat pods with their stalk-like (stipitate) base (see photograph in **Figure 2b**; Isely 1998). *Astragalus ripleyi* can be distinguished from two other tall sympatric *Astragalus* species by several characteristics. *Astragalus ripleyi* has 11 to 21 leaflets, and the pods are laterally compressed. *Astragalus lonchocarpus* has 1 to 9 leaflets, and the pods are dorsiventrally compressed. *Astragalus drumondii* has dense, spreading pubescence, and the pods are trigonous (triangular) in cross-section (Heil and Herring 1999).

References to technical descriptions, photographs, line drawings, and herbarium specimens

Technical descriptions are in Barneby (1964), Martin and Hutchins (1980), Isely (1983), Weber (1990), and Isely (1998). The technical description by Barneby (1964) is particularly complete. A description and photograph of a live plant is published in Colorado Native Plant Society (1997). Photographs of herbarium specimens are on the New York Botanical Garden Web page. A description, photograph of individual plants and the habitat, and a line drawing is also published in Spackman et al. (1997), on the Colorado Natural Heritage Program Web site, and on the New Mexico Rare Plant Technical Council Web site (Heil and Herring 1999). A photograph of the plant is also on the Colorado Natural Areas Program Web site. See References section for Web site addresses. The holotype specimen resides at the California Academy of Sciences Herbarium. An isotype is located at the University of Colorado Herbarium.

Distribution and abundance

Astragalus ripleyi is known from Taos and Rio Arriba counties in New Mexico and Conejos County, Colorado (**Figure 3**). The total range is approximately 975 square miles, an area approximately 65 miles long by 15 miles wide, along the volcanic rim of the San Luis Valley, from near Monte Vista, Colorado to Tres Piedras and Questa, New Mexico (Lightfoot 1995). Within its range it is locally abundant in some years. However, *A. ripleyi* has a patchy distribution and is not found in all of its potential habitat. At the current time, potential habitat is best defined as habitat that from casual observation



Figure 1. Photograph of a flowering *Astragalus ripleyi* plant. Photograph provided by photographer, Teresa Prendusi.

seems suitable for the species, but which is not occupied by it. The information to perform a critical and accurate analysis of habitat requirements is currently unavailable. The species distribution is consistent with it being a substrate endemic associated with the San Juan volcanic field (Tweto 1978). Surveys have been made for the plant in the Jicarilla District of Carson National Forest, and although the vegetation community composition was similar to habitat where it grows, it has not been found there (Heil personal communication 2001, Hooley personal communication 2002). However, the soils in the Jicarilla District are not volcanically derived but are clays and sandy loams from sandstone and sedimentary rocks. As an endemic to volcanic-derived substrates, its

absence may be expected (Tweto 1978, Hooley personal communication 2002).

Within the last 51 years, approximately thirty-eight occurrences have been reported in New Mexico and at least 41 in Colorado (**Table 1**). Occurrence data were obtained from the Colorado Natural Heritage Program, the New Mexico Natural Heritage Program, the Colorado Natural Areas Program, the University of New Mexico Herbarium, New Mexico State University Herbarium, San Juan College Herbarium, Colorado State University Herbarium, the Rocky Mountain Herbarium, the Kathryn Kalmbach Herbarium at Denver Botanical Garden, and the University of Colorado Herbarium.

(a)

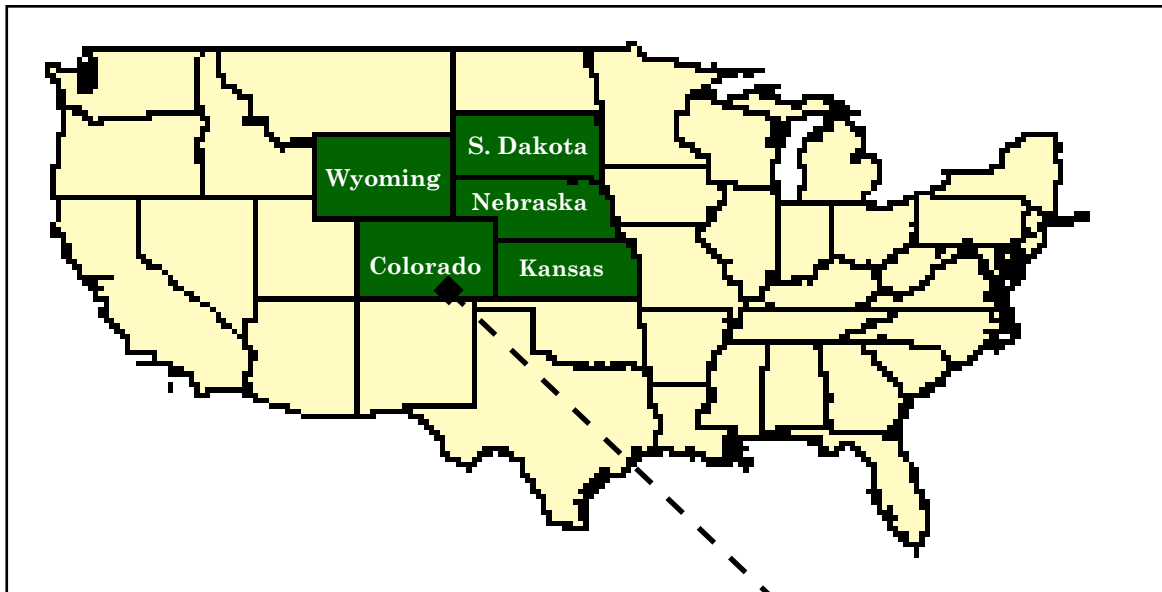


(b)





Figure 2. Close-up photograph of the flowering stalk (a) and stipitate pods (b) of *Astragalus ripleyi*. Photographs provided by photographer, Teresa Prendusi.

States encompassing land managed by Region 2 of the USDA Forest Service



Distribution of Ripley's milkvetch in Colorado (Region 2) and New Mexico (Region 3)

Key:

-  *Astragalus ripleyi*
-  Forest Service land

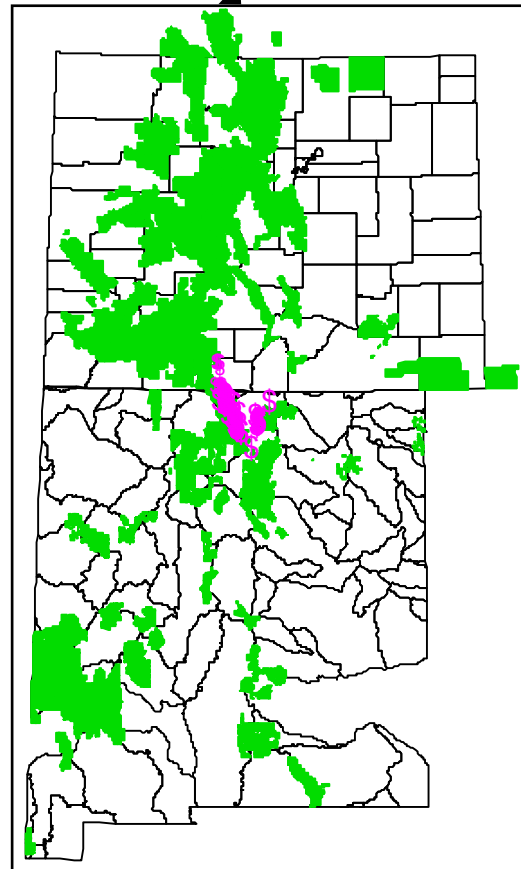


Figure 3. Distribution of *Astragalus ripleyi*.

Some occurrences were combined when individuals were reported only to the nearest section, as in these cases it is unclear as to whether the same population was observed multiple times. In addition, some occurrences may be more appropriately described as sub-occurrences and are indicated as such by the designation in parentheses in the Location column in **Table 1**. Occurrence size ranges from less than ten to approximately one thousand individuals per occurrence. Examples of occurrence size include an estimated 425 individuals over 35 acres, 50 individuals over 50 acres, 10 individuals over 0.25 acres, or an isolated patch of “less than 6 stems observed after a days hiking.” An estimated 229 individuals on approximately 54 acres comprise the population on the San Luis Resource Area (Bureau of Land Management 1989). In New Mexico, occurrences are on the Carson National Forest, land managed by the New Mexico Transportation Department, and private land. In Colorado, occurrences are on the Rio Grande National Forest, the BLM La Jara Resource Area, the Hot Creek and La Jara Wildlife Areas of the Colorado Division of Wildlife, land managed by the Colorado State Board of Land Commissioners and the Colorado Transportation Department, and private land.

Population trend

Astragalus ripleyi was discovered and described relatively recently; therefore, there are few “historical occurrences”. There are insufficient numerical data in the literature, associated with herbarium specimens, or at the Heritage Programs to definitively determine long-term trends over the entire range or within Region 2. Unfortunately, until more recently, the numbers of individuals were not counted or even estimated when populations were found. There are a total of 23 occurrences that have been visited at least twice at one or more years apart. Of those 23 occurrences, 10 only noted the presence of the plants at each visit. Where numbers were counted or estimated at each visit, there was an increase reported at eight occurrences and a decrease at four occurrences, at one of which no plants were found during the most recent visit (**Table 2**). In 2001, surveys were made at two sites where *A. ripleyi* had been documented in an area of Ra Jadero Canyon designated a Colorado Natural Area (see Occurrence No. 32 in **Table 1** and **Table 3**). No plants were found at either site (Karges personal communication 2002). Apparently a gradient of grazing impact was evident over the Natural Area, in that areas seemed impacted from a greater to lesser extent as one walked from lower to upper elevations (Karges personal communication 2002). Considering the location of *A. ripleyi* and the observable impacts of grazing, herbivory was

speculated as one reason for the absence of the species (Karges personal communication 2002).

In the 1980s and 1990s, as more areas within its geographic range were searched and agency personnel became more familiar with the species, the number of documented occurrences increased (Braun 1988, Romero 1992, Lightfoot 1995). Within the last decade more than 24 new occurrences have been reported (Colorado Natural Heritage Program 2002, New Mexico Natural Heritage Program 2002). Population trends are particularly difficult to predict for this species from observations made periodically over relatively short periods of time because there is evidence that the numbers of plants at a given site will vary considerably from year to year in response to environmental conditions, tending to be higher in years with above average precipitation (Burt 1998). In New Mexico between 1988-1989 and 1992, the abundance at several sites significantly increased (Romero 1992). For example, approximately 20 plants were estimated per site on the Tres Piedras District in the Carson National Forest in 1988 and 1989 in contrast to the survey results conducted in 1991 and 1992 when “hundreds” were reported per site (Romero 1992). In contrast, in 1987 approximately 100 plants were observed in the Mogote area of the BLM San Luis Resource Area, Colorado, but no plants could be found after a substantial search in 1989 (Naumann 1990). In addition, despite three days of thorough searching at three sites in the Rio Grande National Forest that were previously documented with over 100 individuals in 1990, each had less than 20 individuals in 1996 (Burt 1997). The differences at each site are likely due to the above average rainfall in 1990, 1991, and 1992 compared to the dry years of late 1980s and 1996 (Romero 1992, Burt 1997, 1999). Weber (1955) described *Astragalus ripleyi* as a “common and conspicuous plant along the roadside between Antonito and the base of Cumbres Pass”. However, *A. ripleyi* has been rarely observed along this route in the last decade (Burt personal communication 2002, Erhard personal communication 2002). It is possible that the 1955 observation was during a wet cycle and that subsequent surveys along that route may have been in dry periods. However, disturbance on the rights-of-way associated with road widening activities, and the invasion of *Melilotus officinalis* may have significantly impacted those roadside populations. Historically populations may also have been impacted by agricultural conversion particularly in Conejos County, Colorado.

No formal monitoring on either Carson National Forest or on BLM land has been done since the mid to late 1990s. Formal monitoring was discontinued

Table 1. Locations of the occurrences of *Astragalus ripleyi*. Locations in Colorado are in Region 2; locations in New Mexico are in Region 3.

State	Arbitrary occurrence no.	County	Date of observations	Location	Ownership	Sources of information ¹
CO	1	Conejos	16-Aug-99	Southwest of Boyles Bridge on the Conejos River.	Rio Grande National Forest	COLO, CNHP
CO	2	Conejos	25-Aug-98	Cold Springs, Fox Creek area.	Rio Grande National Forest	CNHP
CO	3	Conejos	18-Jul-52 and Jul-86	West of Bighorn Creek.	Rio Grande National Forest	CSU Herbarium, COLO, CNHP
CO	3	Conejos	02-Aug-89	Tributary of Bighorn Creek.	Rio Grande National Forest	CSU Herbarium, CNHP
CO	4	Conejos	Jul-86 and 1998	Bighorn Creek area.	Rio Grande National Forest and private	CNHP, COLO, CSU Herbarium
CO	5	Conejos	02-Aug-89	Bighorn Creek area. (likely extends into occurrence 4)	Rio Grande National Forest	CNHP
CO	6	Conejos	1989, 1991, 1994, and 25-Aug-98	Rito Hondo area.	Rio Grande National Forest	CNHP
CO	7	Conejos	29-Jun-99	Ojito Creek area.	Rio Grande National Forest	CNHP
CO	8	Conejos	13-Jul-87	South-southwest of Mogote.	BLM or private	CNHP
CO	9	Conejos	30-Jun-88	Bighorn Creek area.	BLM or private	Collection #5226 at Adams State College Herbarium, CNHP
CO	10	Conejos	21-Jun-87	South-southeast of Canon.	BLM or private	CSU Herbarium, CNHP
CO	11	Conejos	1965, 10-Sep-87, 1989, Jul-99	West of USFS River Spring Work Center.	Rio Grande National Forest	San Juan College Herbarium, Nauman 1990, CNHP
CO	12	Conejos	26-Aug-98	Near Long Canyon.	Rio Grande National Forest	CNHP
CO	13	Conejos	No collection date	Osier area - Conejos Canyon.	Rio Grande National Forest and maybe private	Accession number 973 at Adams State College Herbarium, CNHP
CO	13	Conejos	19-Jul-52	Canyon near Menkehaven.	Unclear location	UNM Herbarium
CO	14	Conejos	1990, 1992, and 24-Sep-99	Hicks Canyon Area to west of Los Mogotes Peaks; covers 10 sections.	Rio Grande National Forest, BLM, Private, State of Colorado	Burt 1999, Naumann 1990, CNHP
CO	15	Conejos	Aug-99	Hicks Canyon Area (part of occurrence 14).	Rio Grande National Forest	CNHP
CO	16	Conejos	1989 and 24-Sep-99	Cemetery, Fox Creek area (part of occurrence 14).	Private	Burt 1999, CNHP
CO	17	Conejos	02-Aug-89	Near gravel pits (part of occurrence 14).	Rio Grande National Forest or private	CSU Herbarium
CO	18	Conejos	09-Sep-92	West of Fox Creek (part of occurrence 14).	BLM and State of Colorado	CNHP
CO	19	Conejos	Aug-89 and Aug-99	South and in Hicks Canyon (part of occurrence 14).	Rio Grande National Forest and may extend onto private land	CNHP
CO	20	Conejos	1935 and 1952	Along Conejos River near gauging station. (Part of occurrence 14).	Private and BLM	CSU Herbarium, COLO, Rocky Mountain Herbarium, CNHP
CO	21	Conejos	08-Aug-99	Los Mogotes area, (within approximately 1 mile of a sub-occurrence in occurrence 14).	BLM	Burt 1999, CNHP
CO	22	Conejos	09-Sep-92	Northwest of Las Mesitas.	BLM	Naumann 1990, CNHP

Table 1 (cont.).

State	Arbitrary occurrence no.	County	Date of observations	Location	Ownership	Sources of information¹
CO	23	Conejos	13-Jul-87	Northwest of Mogote.	BLM	CSU Herbarium
CO	24	Conejos	Jul-89 and Aug-99	South of Ra Jadero Canyon.	BLM or private	CNHP
CO	25	Conejos	No collection date	North of Leandro Canyon.	BLM	Nauman 1990, CNHP
CO	26	Conejos	1989, Jul-92, Aug-99	La Jara Canyon area - Canyon del Rancho (covers 6 sections).	Private and State of Colorado	CNHP
CO	26	Conejos	31-Jul-92 and 15-Aug-99	La Jara Creek Uplands.	Private or BLM	CNHP
CO	27	Conejos	1984 and 11-Sep-87	Near La Jara Creek in La Jara Canyon (part of occurrence 26).	Private and State of Colorado	COLO, Denver Botanic Garden, CNHP
CO	28	Conejos	10-Jul-84	“La Botica”. Above La Jara Creek and below eroded basaltic cliff at south of La Jara canyon (part of 26).	Private, State of Colorado, or BLM	COLO
CO	28	Conejos	31-Jul-92	La Jara Canyon area (part of occurrence 26).	Private, State of Colorado, or BLM	Colorado Natural Areas Program, CNHP
CO	28	Conejos	15-Aug-99	South of La Jara Creek (part of occurrence 26).	Private, State of Colorado, or BLM	Colorado Natural Areas Program, CNHP
CO	29	Conejos	Aug-99, 27-Jul-89, and 08-Oct-90	South of Ra Jadero Canyon.	BLM	CNHP
CO	30	Conejos	08-Oct-90	Approximately 2 miles southeast of Trujillo Canyon.	BLM	Denver Botanic Garden
CO	31	Conejos	26-Jun-99	West of Piedrosa Creek.	Rio Grande National Forest	CNHP
CO	32	Conejos	1986, 1990, Jul-99, and Aug-99	Ra Jadero Canyon.	Private, State of Colorado, or BLM	CNHP
CO	33	Conejos	15-Aug-99	North west end Hot Creek State Wildlife Area.	State of Colorado	CSU Herbarium, CNHP
CO	34	Conejos	17-Aug-99	Mid Hot Creek State Wildlife Area.	State of Colorado	COLO
CO	35	Conejos	17-Aug-99	Poso Creek area.	Private or BLM	CNHP
CO	36	Conejos	19-Aug-86, 08-Oct-90, Aug-92, 17-Jul-99, and Aug-99	East end Ra Jadero Canyon.	BLM	COLO, CSU Herbarium
CO	37	Conejos	1998 and 1999	Tributary of Ra Jadero Canyon.	BLM, State of Colorado, and private	CNHP
CO	38	Conejos	13-Jul-86 and 27-Jul-89	Approximately 2 miles northeast of Terrace Reservoir	Rio Grande National Forest	CSU Herbarium and COLO (1986 specimens), CNHP
CO	39	Conejos	18-Aug-86 and 27-Jul-89	North of Terrace Reservoir.	Rio Grande National Forest	COLO, CSU Herbarium, CNHP
CO	40	Conejos	1965, 1989, and Jul-99	North of Terrace Reservoir.	Rio Grande National Forest	Burt 1999, CNHP
CO	41	Conejos	1965, 1989, and Jul-99	North east Terrace Reservoir (population likely extends into 40).	Rio Grande National Forest and BLM	Burt 1999, CNHP

Table 1 (cont.).

State	Arbitrary occurrence no.	County	Date of observations	Location	Ownership	Sources of information¹
NM	1	Taos	26-May-93	South of Carson and above the Rio Grande River.	State of New Mexico or BLM	San Juan College Herbarium
NM	2	Taos	Jul-92 and Jul-99	On Forest Road 551.	Carson National Forest	Naumann 1990, Romero 1992, NMNHP
NM	3	Taos	08-Jul-55, 13-Jul-92, and May-93	South from Tres Piedras.	Private	Romero 1992, UNM Herbarium, NHNHP
NM	4	Rio Arriba	29-Jul-99	On mesa top above Rio de los Pinos State Recreation Area.	State of New Mexico	Tonne 2000, July - September 1999 surveys for rare and endangered plants on New Mexico State Trust lands
NM	5	Taos	19-Jul-50, 08-Jul-65, and Jun-99	Approximately 4 miles south of Tres Piedras.	Private	UNM Herbarium, COLO, San Juan College [Specimen is topotype]. NMNHP
NM	6	Taos	Sep-87 and Jul-94	Approximately 3 to 4 miles south of Questa.	Carson National Forest	Barneby 1952, Naumann 1990, Lightfoot 1995, UNM Herbarium, NMNHP
NM	7	Taos	1994	Approximately 2 miles south of Questa (likely extends into occurrence 6).	Carson National Forest	Lightfoot 1995
NM	8	Taos	1994	At Hwy 522/Hwy 515 junction area (likely extends into occurrence 6).	Carson National Forest	Lightfoot 1995, NMNHP
NM	9	Taos	1994	Between Alamo Canyon and Garrapata Ridge (likely extends into occurrence 6).	Carson National Forest	Lightfoot 1995, UNM Herbarium, NMNHP
NM	10	Taos	1994	South of Lama on Forest Road 493 (likely extends into occurrence 6).	Carson National Forest	Lightfoot 1995, NMNHP
NM	11	Taos	1994	South of Lama on Hwy 522.	Carson National Forest	Lightfoot 1995, NMNHP
NM	12	Taos	18-Jun-58	Cebolla Mesa.	Carson National Forest	UNM Herbarium, NMNHP
NM	13	Rio Arriba	1994	Approximately 2 miles north of Tres Piedras. Daniel Prairie area.	Carson National Forest	Lightfoot 1995, NMNHP
NM	14	Rio Arriba	24-Jul-92	Plants near Forest Service Road 83.	Carson National Forest	Romero 1992, NMNHP
NM	15	Rio Arriba	11-Jul-83	North west of Tres Piedras.	Private or Carson National Forest	UNM Herbarium, NMNHP
NM	16	Taos	29-Jul-88 and Jul-92	Tres Piedras Administrative site.	Carson National Forest	Naumann 1990, Romero 1992, Braun 1988, NMNHP
NM	17	Rio Arriba	16-Sep-87	Malpais Canyon area.	Carson National Forest or private	NMC Herbarium
NM	17	Rio Arriba	28-Jul-88 and Jul-92	Malpais Canyon.	Carson National Forest	Naumann 1990, Romero 1992, Braun 1988, NMNHP
NM	17	Taos & Rio Arriba	16-Sep-87 and 1994	Malpais Canyon.	Carson National Forest	Naumann 1990, Lightfoot 1995, NMSU herbarium, NMNHP
NM	18	Rio Arriba	spring/summer 1992	Palmer Canyon area.	Carson National Forest	Romero 1992, NMNHP
NM	19	Taos	05-Jul-88	East of Hwy 285 on unpaved road near Tres Piedras.	BLM	Braun 1988, Naumann 1990, NMNHP

Table 1 (concluded).

State	Arbitrary occurrence no.	County	Date of observations	Location	Ownership	Sources of information¹
NM	20	Taos	30-Jul-99	In small arroyo near campground, close to intersection with another dirt road.	BLM or private	Tonne 2000, State land Surveys 1999-2000, UNM Herbarium, NMNHP
NM	21	Rio Arriba	21-Jul-92	Northwest of Lamy Peak.	Carson National Forest	Romero 1992, NMNHP
NM	22	Rio Arriba	1992 and 1994	Mule canyon area (within Tusas grazing allotment).	Carson National Forest	Romero 1992, Lightfoot 1995, NMNHP
NM	23	Taos	06-Aug-97	North of Tres Piedras and west of Hwy. 285.	Carson National Forest	UNM Herbarium, NMNHP
NM	24	Rio Arriba	1993	Stewart Meadows.	Carson National Forest	Lightfoot 1995
NM	25	Taos	1994	South of hwy 196 on road to ski area.	Private	Lightfoot 1995
NM	26	Rio Arriba	28-May-87	Canyon Bancos.	Carson National Forest	Rocky Mountain Herbarium; duplicate specimen at COLO
NM	27	Rio Arriba	08-Jul-88	North east of Gringo stock tank.	Carson National Forest	Naumann 1990, Braun 1988, NMNHP
NM	28	Rio Arriba	03-Aug-89 and 10-Jul-91	Brokoff Mountain area.	Carson National Forest	Naumann 1990, Romero 1992, COLO, NMNHP
NM	29	Rio Arriba	26-Jul-88	Just south of private land on Rio los Pinos.	Carson National Forest	Naumann 1990, Braun 1988, NMNHP
NM	30	Rio Arriba	1993	At Chino cattle watering tank.	Carson National Forest	Lightfoot 1995, NMNHP
NM	31	Rio Arriba	06-Aug-86, 08-Jul-88, Jul-92, and 1993	Chino Peak area, south of Chino tank.	Carson National Forest	Naumann 1990, Romero 1992, Braun 1988, Lightfoot 1995, Allred, K. (4069) BRY. NMNHP
NM	32	Rio Arriba	Jul-88 and Jul-92	North west of Laguna Larga.	Carson National Forest	Braun 1988, Naumann 1990, NMNHP
NM	33	Rio Arriba	22-Jul-92	On Forest Road 78.	Carson National Forest	Romero 1992, NMNHP
NM	34	Rio Arriba	15-Jul-92	North of San Antonio Mtn and at base of mountain.	Carson National Forest	Romero 1992, Lightfoot 1995. NMNHP
NM	35	Rio Arriba	2-Aug-88	North of Bighorn Peak near the Colorado–New Mexico State line.	Carson National Forest	COLO, CNHP
NM	36	Rio Arriba	11-Aug-88 and 28-Jul-92	On mesa/ridge near Forest Road 75.	Carson National Forest	Braun 1988, Romero 1992, Naumann 1990, CNHP
NM	37	Rio Arriba	08-Jul-88, Jul-92, and 1993	Canyon that contains Dale Tank.	Carson National Forest	Braun 1988, Romero 1992, Naumann 1990, CNHP
NM	38	Taos	13-Jul-94	On west side of Costilla Creek Canyon.	Probably private	UNM Herbarium

¹COLO - University of Colorado Herbarium, Boulder, Colorado

CNHP - Colorado Natural Heritage Program unpublished element occurrence records

CSU - Colorado State University

NMNHP - New Mexico Natural Heritage Program unpublished computer database

NMSU - New Mexico State University

UNM - University of New Mexico

Table 2. Number of individuals estimated at sites of *Astragalus ripleyi* visited more than one time.

Arbitrary occurrence no.	1983	1984	1986	1987	1988	1989	1990	1991	1992	1994	1998	1999	Change
NM - 16	P ¹				10				200				Increase
NM - 17					20				200				Increase
NM - 22									P	500			Increase? ²
NM - 28						200		20					Decrease
NM - 32					P				1000				Increase?
CO - 6						425					325		Decrease?
CO - 4			65								6		Decrease?
CO - 8				100		0							Decrease
CO - 11			50									79	Increase
CO - 14						300						500	Increase?
CO - 26		25		25					P				No changes?
CO - 37											500	1000	Increase?
CO - 29						225	225					500	Increase?

¹“P” indicates presence but no numerical data is available.

²? indicates uncertainty.

on the Rio Grande National Forest in 1998 or 1999. However, unpublished reports (Burt 1997, 1998, 1999) and anecdotal accounts (Cassell, Erhard, Long, Sivinski personal communications 2001) indicate that individuals have been observed at several pre-existing sites and new sites have been found within the last five years. In summary, unpublished reports and Natural Heritage Program occurrence data suggest that many occurrences of this species remain extant and sustainable under current land use practices.

Habitat

Astragalus ripleyi occurs in the ecotonal area of the Great Basin and Coniferous Woodland sections of the Southern Rocky Mountain province (Fenneman 1946, McNab and Avers 1994). A noteworthy observation is that *A. ripleyi* invariably grows in areas where plant species diversity is high (Braun 1988). The habitat is generally in open ponderosa pine-Arizona fescue savanna (*Pinus ponderosa*-*Festuca arizonica* association), in open-canopy pinon-juniper woodlands with an Arizona fescue (*F. arizonica*) understory, or on the edges of closed-canopy ponderosa pine and mixed conifer forest (Lightfoot 1995). These plant associations are classified by the U.S. Forest Service as: Pipo/Fear – Ponderosa pine/Arizona fescue (Johnston 1987, Larson and Moir 1992) and Abco-Psme/Fear – *Abies concolor*-*Pseudotsuga menziesii*/Arizona fescue, and Pied-Jumo/Cemo – *Pinus edulis* - *Juniperus monosperma*/ *Cercocarpus montanus* (Johnston 1987). However, occurrence observations indicate the habitat is more variable, particularly in New Mexico (USFS Region 3).

Occurrences are frequently in shrub-dominated habitat such as pine-oak (*Quercus gambelii*) communities, pinon-juniper sagebrush, sagebrush communities, and *Chrysothamnus viscidiflorus* (yellow rabbitbrush) meadows. Arizona fescue appears to be the most commonly associated grass, but areas dominated by blue grama (*Bouteloua gracilis*) and needle-and-thread (*Stipa* spp.) have also been recorded. The Great Basin Desert scrub communities in which *A. ripleyi* occurs (Sivinski and Lightfoot 1992) have not been critically defined, and without more detailed information further habitat typing according to USFS guidelines cannot be made. Considering the Rocky Mountain Resource Information System habitat structural stage codes of Region 2, *A. ripleyi* grows in grass-forb, shrub-seedling, sapling-pole, and at the edge of mature structural stages, respectively codes 1, 2, 3a, 3b and 4a and 4b, after Oliver and Larson (1996). Summaries of the habitat encountered at each occurrence site are listed in **Table 3**. A photograph of the habitat in New Mexico is shown in **Figure 4**.

Astragalus ripleyi is often observed under the canopy, or within the stems, of shrubs such as *Artemisia tridentata* (big sagebrush), *Quercus gambelii* (gambel oak), *Chrysothamnus* spp. (rabbitbrush), and *Juniperus* spp. (juniper). The association with shrubs may be due to a favorable microclimate or advantageous soil environment for germination and seedling establishment. In addition, or alternatively, growing in the midst of shrubs affords protection from large herbivores and may be a consequence of current or historical grazing pressures (Naumann 1990, Lightfoot

Table 3. Habitat summaries for *Astragalus ripleyi* occurrence sites. Habitat summary information is direct (e.g. use of scientific vs. common names) from herbarium labels, element occurrence reports, etc.

State	Arbitrary occurrence no.	County	Habitat summary
CO	1	Conejos	Plants occur in a variety of microhabitats in open grassland, sparse sagebrush (<i>Artemisia tridentata</i>) with scattered <i>Pinus ponderosa</i> , <i>Pinus edulis</i> and <i>Populus tremuloides</i> . On east and northeast facing slopes with open grasslands, sparse sagebrush, scattered ponderosa pine, <i>Pinus edulis</i> , and <i>Populus tremuloides</i> .
CO	2	Conejos	With <i>Festuca arizonica</i> , <i>Chrysothamnus viscidiflorus</i> , <i>Chrysothamnus greenii</i> , <i>Muhlenbergia montana</i> , <i>Chrysothamnus vaseyi</i> , <i>Potentilla hippiana</i> , <i>Koeleria macrantha</i> , <i>Eriogonum racemosum</i> and <i>Picradenia richardsonii</i> .
CO	3	Conejos	In meadow (1952). On slopes (0-20% incline) with all aspects on gravelly loam derived from the volcanic Los Pinos formation (1986).
CO	3	Conejos	On slopes (0-20% incline) on gravelly loam soils derived from Los Pinos formation.
CO	4	Conejos	Site is on a north, northwest facing slope on a dry terrace (montane meadow) of ephemeral stream. Rocky loam soil, ~35% bare ground in <i>Festuca arizonica</i> habitat type.
CO	5	Conejos	On slopes (0-3%) with southern aspects on silty loam soil derived from the Hinsdale formation (volcanic).
CO	6	Conejos	On dry slopes (0-30%) of rocky silty loam soils derived from the Los Pinos formation. Plants in <i>Festuca arizonica</i> habitat type, some plants with <i>Chrysothamnus</i> and lupine species in the understory of aspen, mixed conifer (<i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> , <i>Abies concolor</i>).
CO	7	Conejos	Information unavailable.
CO	8	Conejos	Sandy soil; Hinsdale (volcanic) formation. NW aspect on a steep slope with <i>Pinus edulis</i> , <i>Pinus ponderosa</i> , <i>Juniperus</i> spp., <i>Bouteloua</i> spp.
CO	9	Conejos	Grassland.
CO	10	Conejos	On north northwest facing slope in moist loam derived from the Hinsdale or Los Pinos formation. Associated taxa include <i>Pinus ponderosa</i> , <i>Artemisia</i> spp., <i>Chrysothamnus</i> spp., <i>Poa</i> spp., <i>Festuca</i> spp.
CO	11	Conejos	Growing in sandy loam derived from volcanic alluvium under ponderosa pine savannah with <i>Chrysothamnus</i> spp., <i>Festuca arizonica</i> and <i>Lupinus kingii</i> .
CO	12	Conejos	In dry open level area in sandy, silt, gravel and peat soil (9360 ft). Associated taxa include <i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> , <i>Chrysothamnus vaseyi</i> , <i>Chrysothamnus parryi</i> , <i>Eriogonum racemosum</i> , <i>Festuca saximontana</i> , <i>Festuca arizonica</i> , <i>Muhlenbergia montana</i> , <i>Artemisia carruthii</i> , <i>Koeleria macrantha</i> , <i>Poa pratensis</i> . Communities surround and “intermingle” with site.
CO	13	Conejos	No information.
CO	13	Conejos	No information.
CO	14	Conejos	On north-northeast facing slopes (2-20%) amongst scattered ponderosa pine and douglas fir in open grassland and low shrubland dominated by species (<i>Gutierrezia sarothrae</i> , <i>Heterotheca villosa</i>) that increase after disturbance. Associated taxa include <i>Bouteloua gracilis</i> , <i>Artemisia frigida</i> . In 1999, <i>Festuca</i> spp. was present at at least six of the sub-occurrences.
CO	15	Conejos	Many weedy species including smooth brome and sweet yellow clover (1989). Plants on slopes (0-15%) on a stony clay loam. Associated taxa include <i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> , <i>Populus</i> spp., <i>Festuca arizonica</i> .
CO	16	Conejos	On level sites (slope 0-3%) on cobbly clay loam. Associated taxa include <i>Hymenoxys richardsonii</i> , <i>Chrysothamnus viscidiflorus</i> , <i>Castilleja</i> spp., blue grama, horse brush, <i>Eriogonum racemosum</i> , <i>Eriogonum elatum</i> , <i>Penstemon wetherillii</i> .

Table 3 (cont.).

State	Arbitrary occurrence no.	County	Habitat summary
CO	17	Conejos	No information.
CO	18	Conejos	Plants in low area extending north into a drainage. Plants in deeper soil on a rocky substrate with <i>Festuca arizonica</i> , <i>Symphoricarpos oreophilus</i> .
CO	19	Conejos	On northeast facing slopes (0-15% incline) in stony clay loam soils in mixed savana with <i>Festuca arizonica</i> , <i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> , <i>Populus tremuloides</i> , <i>Juniper monosperma</i> , <i>Abies concolor</i> .
CO	20	Conejos	With <i>Chrysothamnus</i> spp., annual <i>Lupinus</i> spp., and <i>Penstemon secundiflorus</i> .
CO	21	Conejos	In deeper soils on rocky substrate derived from the Hinsdale formation. Sites with northeast aspect with <i>Festuca arizonica</i> , <i>Symphoricarpos oreophilis</i> , <i>Astragalus hallii</i> , <i>Eriogonum racemosum</i> , <i>Kobresia</i> spp., <i>Lupinus</i> spp.
CO	22	Conejos	No information.
CO	23	Conejos	No information.
CO	24	Conejos	In silty loam on orth-northeast and east facing slopes (0-20%) in open ponderosa pine, pinon juniper savanna and at forest edges.
CO	25	Conejos	No information.
CO	26	Conejos	Plants on northwest- and east- facing, lower slopes (of up to 60% incline) in gravel, clay to rocky loam soils derived from volcanic formation on slopes with <i>Artemisia tridentata</i> , <i>Chrysothamnus nauseosus</i> , <i>Rhus trilobata</i> under open <i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> and/or <i>Pinus edulis-Juniperus monosperma</i> .
CO	26	Conejos	<i>Poa pratensis</i> abundant. <i>Cirsium arvense</i> (canada thistle) presently primarily in the creek bottom (1999).
CO	27	Conejos	Dry bouldery hillside between basalt rock and creek in P-J woodland. <i>Rhus trilobata</i> , <i>Chrysothamnus nauseosus</i> , <i>Ribes</i> spp., <i>Yucca</i> spp., <i>Opuntia</i> spp., <i>Berberis</i> spp.
CO	28	Conejos	With sagebrush.
CO	28	Conejos	Northeast-facing sloping (25% incline) meadow.
CO	28	Conejos	On dry north-northeast facing slopes (25%) on gravel and clay soils dominated by <i>Artemisia tridentata</i> in open and at edge of <i>Pinus ponderosa</i> and <i>Pseudotsuga menziesii</i> . <i>Astragalus ripleyi</i> usually associated with shrubs; typically the ground is bare between shrubs.
CO	29	Conejos	In silty loam soils at forest edges and in open <i>Pinus ponderosa</i> and pinon-juniper savannah.
CO	30	Conejos	North slope among shrubs
CO	31	Conejos	On open, gentle undulating slopes (0-5%) in silty loam soils in very sparse <i>Pinus ponderosa</i> , <i>Pseudotsuga menziesii</i> , <i>Pinus edulis</i> , <i>Sabina monosperma</i> . Associated species include <i>Picradenia richardsonii</i> , <i>Heterotheca villosa</i> , <i>Chondrosium gracile</i> .
CO	32	Conejos	Densest populations in 1999 were on upper slopes near aspen. In 1990 plants growing on north-northeast facing slopes (0-20%) in stony loam soils in grassland just below ponderosa pine, aspen or pinon-juniper. Frequently growing in shrub refugia. Associated species include <i>Festuca arizonica</i> , <i>Eriogonum racemosum</i> , <i>Symphoricarpos</i> spp., <i>Melilotis</i> spp. <i>Hymenoxys richardsonii</i> was very abundant in 1990. In 1986 <i>Astragalus ripleyi</i> growing on north-facing slopes in loam soils in grassland just below level of ponderosa pine, In 1986, rare with <i>Agropyron</i> spp., <i>Hymenoxys</i> spp. and <i>Symphoricarpos</i> spp.; <i>Hymenoxys richardsonii</i> very abundant.
CO	33	Conejos	On sparsely vegetated slopes and in gullies. Bare ground and rocks abundant. Dominant associated taxa include <i>Heterotheca villosa</i> , <i>Eriogonum racemosum</i> , <i>Bouteloua gracilis</i> .

Table 3 (cont.).

State	Arbitrary occurrence no.	County	Habitat summary
CO	34	Conejos	On north-facing slopes above Poso Creek.
CO	35	Conejos	On open north-facing slope (on toeslope) with sparse pinon-juniper habitat. Weedy riparian area.
CO	36	Conejos	On open slopes (1992). Rare with <i>Agropyron</i> spp., <i>Hymenoxys</i> spp. and <i>Symphoricarpos</i> spp.
CO	37	Conejos	On gentle slopes (0-5%) in silt loam soil with sparse <i>Pinus edulis</i> , <i>Sabina monosperma</i> and <i>Pinus ponderosa</i> .
CO	38	Conejos	On north-northwest facing slopes in brown loam soil. Associated taxa include <i>Koeleria</i> spp., <i>Bromus</i> spp., <i>Hypoxis rigida</i> , <i>Leptodactylon</i> spp., <i>Penstemon ophianthus</i> , <i>P. crandalli</i> , <i>Symphoricarpos</i> spp., <i>Lupinus kingii</i> , <i>Eriogonum racemosum</i> , <i>Chrysothamnus nauseosus</i> .
CO	39	Conejos	Infrequent on mostly north-facing slopes in gravelly soil, with <i>Bouteloua</i> spp., <i>Muhlenbergia</i> spp. among <i>Cercocarpus</i> spp. and <i>Symphoricarpos</i> spp. <i>Hypoxis rigida</i> abundant.
CO	40	Conejos	On northeast-northwest facing slopes (0-30% incline) in open to partially wooded (<i>Pinus edulis</i> - <i>Juniperus monosperma</i> and <i>Pinus ponderosa</i>) areas.
CO	41	Conejos	On northeast-northwest facing slopes (0-30% incline) in open to partially wooded (<i>Pinus edulis</i> - <i>Juniperus monosperma</i> and <i>Pinus ponderosa</i>) areas .
NM	1	Taos	Information unavailable.
NM	2	Taos	Typic Haplustalfs, fine loamy, mixed, mesic. <i>Artemisia tridentata</i> , <i>Pinus edulis</i> , <i>Juniperus monosperma</i> , <i>Hymenoxys richardsonii</i> , <i>Poa fendleriana</i> , <i>Bromus tectorum</i> , <i>Agropyron smithii</i> .
NM	3	Taos	Gravelly sandy loam. Sagebrush community.
NM	4	Rio Arriba	In rocky clay with <i>Artemisia tridentata</i> , <i>Bouteloua gracilis</i> , <i>Oryzopsis hymenoides</i> , <i>Elymus elymoides</i> , <i>Gutierrezia</i> spp., <i>Ipomopsis aggregata</i> with scattered <i>Juniperus monosperma</i> and <i>Pinus edulis</i> .
NM	5	Taos	Sagebrush community.
NM	6	Taos	Clay, fine sand soil with <i>Quercus gambelii</i> , <i>Pinus ponderosa</i> , <i>Pinus edulis</i> , <i>Juniperus</i> spp., <i>Cercocarpus montanus</i> .
NM	7	Taos	Oak thicket.
NM	8	Taos	Information unavailable.
NM	9	Taos	<i>Pinus edulis</i> , <i>Juniperus</i> spp., <i>Pinus ponderosa</i> . Very little oak present.
NM	10	Taos	Information unavailable.
NM	11	Taos	Information unavailable.
NM	12	Taos	On slopes (0-2% incline) in loam soils in pinyon-juniper-sagebrush vegetation type.
NM	13	Rio Arriba	Oak brush, ponderosa pine, pinon, juniper, big sage.
NM	14	Rio Arriba	Gravelly sandy loam. <i>Quercus gambelii</i> , <i>Pinus ponderosa</i> , <i>Pinus edulis</i> , <i>Aster bigelovii</i> , <i>Castilleja</i> spp., <i>Agropyron cristatum</i> , <i>Sitanion hystrix</i> .
NM	15	Rio Arriba	Growing in open ponderosa pine forest, in granite soil.
NM	16	Taos	Gravelly sandy loam. <i>Artemisia tridentata</i> , <i>Pinus ponderosa</i> , <i>Aster bigelovii</i> , <i>Melilotus officinalis</i> , <i>Linum lewisii</i> , <i>Agropyron cristatum</i> , <i>Agropyron trachycaulum</i> , <i>Sitanion hystrix</i> .
NM	17	Rio Arriba	Information unavailable
NM	17	Rio Arriba	Fine, loamy [soil]. <i>Artemisia tridentata</i> , <i>A. nova</i> , <i>Pinus ponderosa</i> , <i>Agropyron smithii</i> , <i>Bouteloua gracilis</i> , <i>Sitanion hystrix</i> , <i>Festuca</i> spp., <i>Hymenoxys odorata</i> .

Table 3 (concluded).

State	Arbitrary occurrence no.	County	Habitat summary
NM	part of 17	Taos & Rio Arriba	Sagebrush plain under scattered ponderosa pine, pinyon, juniper, w/ <i>Chrysothamnus nauseosus</i> , <i>C. viscidiflorus</i> , <i>Yucca</i> spp., <i>Astragalus drummondii</i> , <i>A. tenellus</i> , <i>Eriogonum racemosum</i> , <i>Orthocarpus purpureoalbus</i> ; some plants in mowed grassy shoulder. Rocky. <i>Pinus ponderosa</i> , <i>Artemisia tridentata</i> , <i>Quercus gambelii</i> , <i>Artemisia nova</i>
NM	18	Rio Arriba	No information
NM	19	Taos	No information
NM	20	Taos	In fine clay alluvium. <i>Artemisia tridentata</i> , <i>Bouteloua gracilis</i> , <i>Chrysothamnus nauseosus</i> , <i>Gutierrezia sarothrae</i> , <i>Oxytropis lambertii</i> .
NM	21	Rio Arriba	Coarse loamy mixed sandy loam. <i>Pinus ponderosa</i> , <i>Artemisia tridentata</i> , <i>Castilleja</i> spp., <i>Festuca arizonica</i> , <i>Danthonia intermedia</i> .
NM	22	Rio Arriba	Oak brush and big sage
NM	23	Taos	On clayey loam with basalt cobble under crown of <i>Juniperus scopulorum</i> with <i>Ribes</i> and <i>Symphoricarpos</i> species.
NM	24	Rio Arriba	No information
NM	25	Taos	<i>Pinus edulis</i> , <i>Juniperus scoparium</i> , <i>Artemisia tridentata</i> , <i>Cercocarpus montanus</i>
NM	26	Rio Arriba	On stream floodplain and adjacent sandstone mesas.
NM	27	Rio Arriba	South side of a densely timbered canyon
NM	28	Rio Arriba	Broad bench with deep soil along drainage. Sandy. <i>Festuca</i> grassland with scattered <i>Pseudotsuga menziesii</i> and <i>Pinus ponderosa</i> . <i>Populus tremuloides</i> , <i>Potentilla fruticosa</i> , <i>Carex</i> spp., <i>Astragalus</i> spp., <i>Festuca thurberi</i> , <i>Festuca arizonica</i> .
NM	29	Rio Arriba	Growing under the outer canopy of the ponderosa pine, in pine duff
NM	30	Rio Arriba	Information unavailable
NM	31	Rio Arriba	Cobbly loam. <i>Pinus ponderosa</i> , <i>Gilia</i> spp., <i>Lupinus</i> spp., <i>Festuca arizonica</i> , <i>Danthonia intermedia</i> , <i>Sitanion hystrix</i> . Assoc taxa: <i>Pinus ponderosa</i> , <i>Festuca arizonica</i> , <i>Danthonia intermedia</i> , <i>Bouteloua gracilis</i> , <i>Muhlenbergia filiculmis</i>
NM	32	Rio Arriba	Volcanic, cobbly loam. <i>Artemisia nova</i> , <i>Hymenoxys richardsonii</i> , <i>Agropyron</i> spp., <i>Artemisia nova</i> , <i>Quercus gambelii</i> , <i>Hymenoxys richardsonii</i> , <i>Castilleja</i> spp., <i>Agropyron smithii</i> , <i>Bouteloua gracilis</i> , <i>Carex</i> spp.
NM	33	Rio Arriba	Gravelly, sandy loam. <i>Pinus ponderosa</i> , <i>Lupinus</i> spp., <i>Gilia</i> spp., <i>Festuca arizonica</i> , <i>Danthonia intermedia</i> , <i>Sitanion hystrix</i> , <i>Pinus ponderosa</i> , <i>Lupinus</i> spp., <i>Gilia</i> spp., <i>Festuca arizonica</i> , <i>Danthonia intermedia</i> , <i>Sitanion hystrix</i>
NM	34	Rio Arriba	Cobbly loam. <i>Populus tremuloides</i> , <i>Quercus gambelii</i> , <i>Castilleja</i> spp., <i>Agropyron cristatum</i> , <i>Sitanion hystrix</i> , <i>Bouteloua gracilis</i> , Arizona fescue
NM	35	Rio Arriba	Volcanic parent rock, silty loam
NM	36	Rio Arriba	Deep gravelly loam, <i>Artemisia nova</i> , <i>Chrysothamnus</i> spp., <i>Eriogonum</i> spp., <i>Hymenoxys richardsonii</i> , <i>Oryzopsis hymenoides</i> , <i>Bouteloua gracilis</i> , <i>Festuca arizonica</i> .
NM	37	Rio Arriba	Deep, cobbly loam, ustochrepts. <i>Chrysothamnus</i> spp., <i>Pinus ponderosa</i> , <i>Artemisia tridentata</i> , <i>Lupinus</i> spp., <i>Castilleja</i> spp., <i>Calochortus</i> spp., <i>Bouteoua gracilis</i> , <i>Festuca arizonica</i> , <i>F. ovina</i> , <i>Muhlenbergia montana</i> .
NM	38	Taos	Growing with <i>Artemisia tridentata</i> and <i>Cercocarpus montanus</i> .



Figure 4. *Astragalus ripleyi* habitat in New Mexico. Note the cream flowers of *A. ripleyi* in the foreground. Photograph provided by photographer, Teresa Prendusi.

1995, Sivinski personal communication 2001). In one severely overgrazed, very weedy *Chrysothamnus viscidiflorus* meadow that had apparently been planted with *Agropyron cristatum* (crested wheatgrass) in the past, *A. ripleyi* plants were confined to large shrubs. The entire meadow appeared to be similar habitat but the plants were only in a few clumps. This 1998 observation (Colorado Natural Heritage Program 2002) suggests that either some habitat modification is tolerated or that habitat is not strictly confined to the limited types described in the past (Naumann 1990, Lightfoot 1995). It is unclear as to how many years had passed since the seeding took place, and one may conjecture that the root systems were present prior to habitat modification and that the surviving plants are relics.

Tree species associated with *Astragalus ripleyi* habitat are *Abies concolor*, *Juniperus monosperma*, *J. osteosperma*, *J. scopulorum*, *Pinus edulis*, *P. ponderosa*, *Populus tremuloides*, and *Pseudotsuga menziesii*. Associated shrub species include *Artemisia frigida*, *A. nova*, *A. tridentata*, *Chrysothamnus Greenei*, *C. nauseosus*, *Cercocarpus montanus*, *Potentilla fruticosa*, *Quercus gambelii*, *Rhus trilobata*, and *Symphoricarpos oreophilus*. Associated forb species include *Antennaria* spp., *Aster bigelovii*, *Astragalus drummondii*, *A. hallii*, *A. lonchocarpus*, *Calochortus* spp., *Castilleja* spp.,

Erigeron spp., *Eriogonum* spp., *Eriogonum racemosum*, *Gilia* spp., *Gutierrezia sarothrae*, *Heterotheca villosa*, *Hymenoxys odorata*, *Linium lewisii*, *Melilotus* spp., *Melilotus officinalis*, *Oxytropis lambertii*, *Penstemon griffinii*, *P. secundiflorus*, *Picradenia richardsonii*, *Taraxacum officinale*, and *Vicia americana*. Associated grass and grass-like species include *Agropyron cristatum*, *A. trachycaulum*, *A. smithii*, *Blepharoneuron tricholepis*, *Bouteloua gracilis*, *Bromus tectorum*, *Carex* spp., *Danthonia intermedia*, *Elymus elymoides*, *Festuca arizonica*, *F. ovina*, *F. thurberi*, *Koeleria* spp., *Muhlenbergia* spp., *Muhlenbergia filiculmis*, *M. montana*, *Oryzopsis micrantha*, *Poa fendleriana*, *P. pratensis*, *Stipa* spp., *Stipa comata*, and *S. hymenoides*.

The Colorado portion of the species' range falls almost entirely within the 16 to 20 inch average rainfall isohyet (Naumann 1990), and the New Mexico portion receives 14 to 32 inches of rainfall per year depending upon elevation (Lightfoot 1995). Plants occur at elevations between 5,450 and 9,360 feet, which is a considerable extension from 7,000 to 8,250 feet reported by Barneby (1964). However, where elevation was reported, the majority of occurrences are between 8,500 and 9,000 feet (**Figure 5**). Plants are found on level ground to slopes of approximately 30 percent with the most occurrences occurring on slopes of 10 percent or

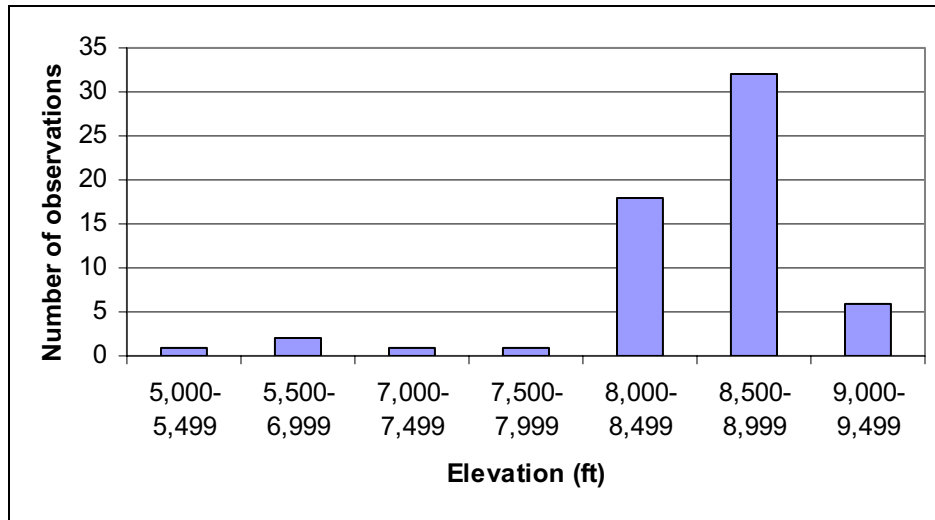


Figure 5. Graphic representation of the elevation distribution of *Astragalus ripleyi* populations. Graph does not include occurrences where elevation was not reported.

less. *Astragalus ripleyi* has been found on slopes facing all aspects. The tendency to find them in east-west trending drainages suggests a preference for more mesic sites in otherwise dry environments (Lightfoot 1995).

Astragalus ripleyi occurs exclusively on volcanic derived soils (see Distribution and abundance section). These include tuffaceous ash-flow sheets, basaltic flows, and reworked volcanic materials, for example Treasure Mountain Tuff, Masonic Park Tuff, Carpenter Ridge Tuff, Los Pinos formation and Hinsdale formation (Erhard 1994, Lightfoot 1995). In New Mexico, the soils that overlay volcanic rock are generally loamy mixed soils. One report in New Mexico indicates plants grow in loamy clays overlying granitic bedrock (U.S. Fish and Wildlife 1993, New Mexico Natural Heritage Program 2001). However, the town-range-section information places the occurrence on volcanic derived soils. The occurrence is most likely on soils derived from plutonic rocks that are characteristically medium- to coarse-grained granitic textured (geological code: Xp; Anderson et al. 1997). Soils on this geological formation may well appear “granitic” rather than “volcanic” in the field (Reiter personal communication 2002). The precision of the occurrence data was such that it may alternatively be on the adjacent Los Pinos geological formation (geological code: Tlp) that comprises volcanoclastic conglomerate interbedded with basaltic flows (Anderson et al. 1997).

Reproductive biology and autecology

Astragalus ripleyi reproduces by seed. However, plants behave as long-lived individuals that primarily

allocate resources to survival of the individual rather than to reproduction (Burt 1997, 1998, 1999). *Astragalus ripleyi* does not compensate for herbivore activity by producing more stems or leaves to replace those that are lost. Instead, it tends to produce fewer reproductive organs and, presumably builds up root stock reserves for growth in subsequent years. Species with a similar life form and regenerative strategy were characterized as stress tolerant or stress tolerant-competitive by Grime et al. (1988) or as k-selected species that have a long life span in relatively stable habitats by MacArthur and Wilson (1967).

Astragalus species are generally insect pollinated (Geer and Tepidino 1993), and *A. ripleyi* appears to be no exception. Bees and ants have been observed on flowers, and Burt (1997) reported that bumblebees (*Bombus ternaries*) were the most common arthropod visitor. As part of the same study Burt (1997) bagged flowering stems to exclude pollinators; these produced no fruits, while the unbagged stems did. This result may be due to one of several conditions. Absence of seed set may indicate that *A. ripleyi* is self-incompatible. *Astragalus lonchocarpus*, the widespread congener, is “slightly self-compatible” (Karron 1987). Alternatively, the plants may be self-compatible and the absence of seed set may indicate that there is a need for insect-mediated pollen transfer either within or between flowers, or that the reproductive organs did not mature at same time. For example, the pollen (male organs) matured before the female organs (protandry). In addition, because no hand pollinations were performed, the environment of the pollination bag may have caused sterility and cannot be completely discounted.

Fewer reproductive stems and fewer fruits per flowering stems were observed in years with less precipitation at four different study areas in the Rio Grande National Forest (Burt 1999). This observation was not statistically established but was a trend observed from graphs of raw data. In the dry years, Burt (1999) also observed fewer bees, which may have been due to the dry conditions or a local phenomenon due to the fewer number of flowers. Bees are density-dependent foragers and will avoid populations where the reward (i.e. flowers) is potentially low (Heinrich 1976, Thomson 1982, Geer and Tepedino 1993). Therefore, either fewer fruit were set for lack of pollinators or because of inadequate available photosynthate due directly to the drought.

Astragalus ripleyi flowers from June into July. The earliest date flowers have been reported is June 5. Within a population, a high percentage, frequently on the order of 80 to 90 percent, of individuals produce flowers and pods (Romero 1992, Colorado Natural Heritage Program 2002, New Mexico Natural Heritage Program 2002). Pods tend to be retained on the plant through at least October (Lightfoot 1995). Barneby (1964) described that the *Lonchocarpus* pods dehisce apically and then downward through one or both sutures. It has not been reported whether the pods of *A. ripleyi* open, and thus lose some seed, prior to their dropping off the plant in the fall or if the seeds are retained in the pods until the latter are off the plant. The patchy nature of its spatial distribution suggests that seed dispersal may often be limited and localized around the parent plant. Seed dispersal has been speculated to be effected by ants, mice, and other seed storers, tumbling of dried plants, and wind or water transport. However, little evidence has been documented for any particular mechanism (Braun 1988, Naumann 1990, Lightfoot 1995, Anderson personal communication 2002). Rodents cache fruits in small piles near plants and likely contribute to short-distance dispersal (Burt 1999).

There are no data on longevity of seed or seed bank dynamics. Scarified seeds germinate readily in the year they are produced (Burt 1999); however, natural scarification may take several years to occur. Studies on seed germination rates have not been published, but two unpublished reports suggest germination rates are good. An informal report described that approximately 33 percent of seeds germinated (Martin personal communication 2002), and another reported that 78 to 80 percent of scarified seeds germinated within 3 to 14 days in a greenhouse (Burt 1999). Burt (1997) observed that only scarified seed germinated, and such mandatory scarification would be expected, as many members of

the Leguminosae have a hard, impermeable seed coat (Bewley and Black 1982). The impermeable seed coat also imposes a form of dormancy that may confer some tolerance to heat and thus wildfire (Whelan 1997). *Astragalus amblytropis*, another perennial endemic to volcanic soils, demonstrated a greater than 96 percent *in vitro* germination rate, but no natural seed germination was observed in the field (Rittenhouse and Rosentreter 1994). It may be that observations on germination in the field are closely linked to seedling establishment. Seeds that germinated in the soil but then died within a few days may easily be overlooked in a field situation.

The degree of reported seed predation by insects is variable but may be the cause of significant seed loss in some years (Coles 1996, Burt 1997). Evidence of seed predation can be found in some herbarium specimens. For example one of the specimens collected by O’Kane (specimen collection #2601 in 1996) at the University of Colorado Herbarium had “pin-prick” holes, most likely present prior to collection, in the legumes.

Astragalus ripleyi seedling establishment was very poor in two *in vitro* seed germination studies (Martin 1990, Burt 1999). Inappropriate soil conditions or inadequate moisture were speculated to be the cause of poor seedling establishment. However, *in vitro* germination rate may not reflect the situation in the field. There is no information on seedling ecology, and the rates of recruitment and mortality in the field are unknown. Few age and size class data are available but plants with large, robust and flowering stems one year may appear small and immature the next (Burt 1999). This observation makes casual comments on seedling presence difficult to evaluate.

Hybridization between *Astragalus* species is very rare (Liston 1992, Spellenberg personal communications 2002 and 2003). In accordance with this report, there is no evidence of hybridization between *A. ripleyi* and other *Astragalus* species. *Astragalus lonchocarpus* is a closely related species that grows within the range of *A. ripleyi*. There appears to be some differences in “typical” habitat. For example, *A. lonchocarpus* grows in salt desert scrub as well as piñon-juniper communities (Welsh et al. 1998). The frequency with which they become sympatric is not known and no intermediates between these species have been observed (Lightfoot 1995).

Demography

Demographic studies on *Astragalus ripleyi* have not been published. Studies undertaken on the

Rio Grande National Forest collected some valuable demographic data over a period of three years (Burt 1997, 1998, 1999). Unfortunately only limited conclusions can be drawn as the data were not fully analyzed, but some deductions and inferences can be made. From observations made during this three-year study, it is clear that individuals do not follow a linear progression from seedling to non-reproductive individual to reproductive individual but may be reproductive one year, small vegetative plants the next, or may remain dormant for at least one year without any aboveground stem (Burt 1999). In addition, plant size may bear no relation to age; plants that were large and reproductive one year may appear to be small juveniles the next (Burt 1999).

The life cycle diagram in **Figure 6** is constructed after that designed by Burt (1999). In this life cycle diagram, “vegetative” rather than “juvenile” is used to

describe the state of the plants to emphasize that they may have flowered in previous years. In some years stems die before flowering. Insufficient precipitation after sprouting has been speculated as the reason (Burt 1999). “Death”, of course, is defined as death of the whole individual and not just the annual death of the aboveground parts. As with many relatively long-lived perennial plants, *Astragalus ripleyi* appears to allocate a significant portion of its resources to maintain the root system, sometimes foregoing sexual reproduction. This characteristic and the apparent low importance of annual seed germination and seedling recruitment suggests that, with respect to life cycle components, it has more in common with woody rather than herbaceous plants. Growth and survival are the important life cycle components that characterize woody plants (Silvertown et al. 1993). However, the true importance of seed production and seedling recruitment remains to be clarified.

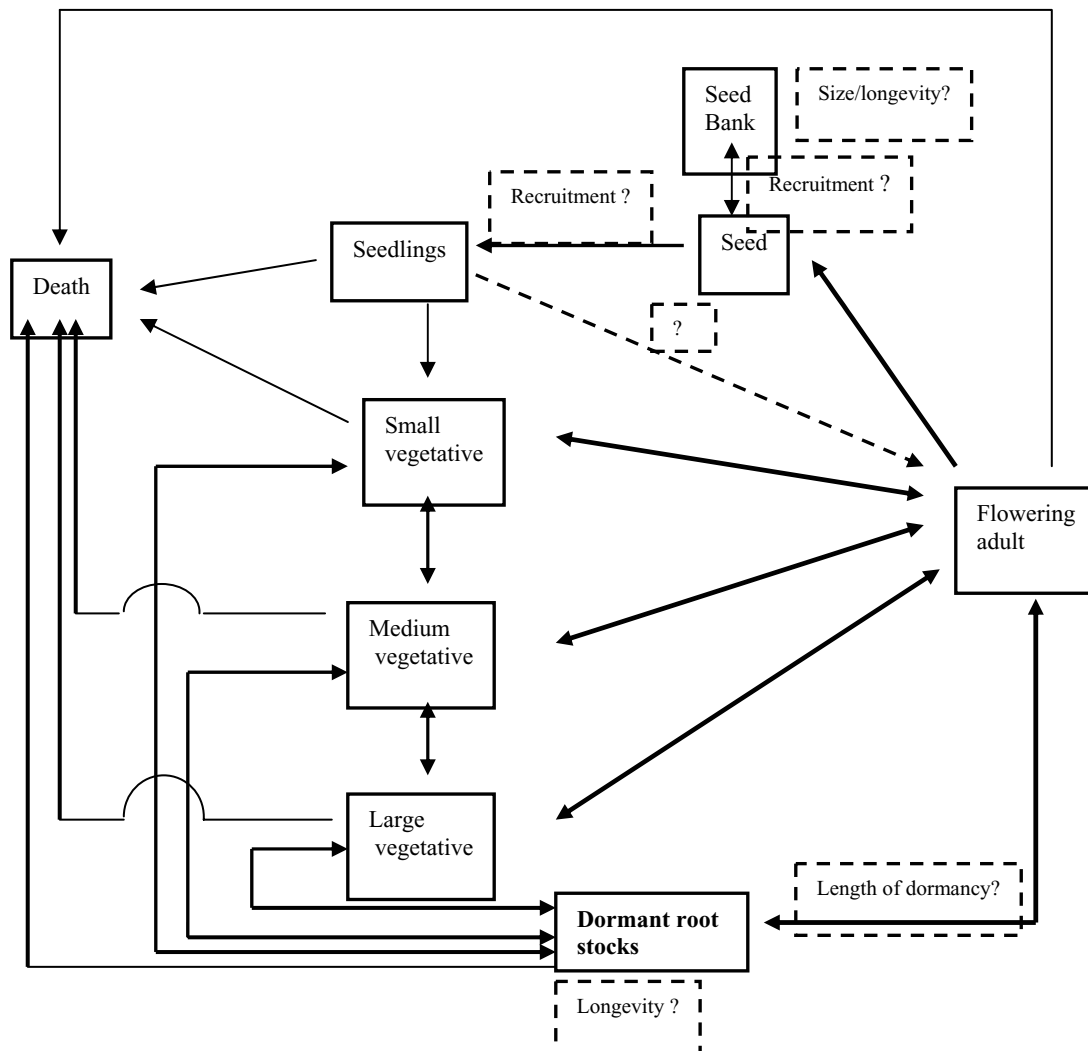


Figure 6. Life cycle diagram of *Astragalus ripleyi*.

Astragalus ripleyi may be a “fire evader”, having long-lived “propagules” (in this case roots) stored in the soil (Rowe 1983 in Whelan 1997), rather than a “stress tolerator” (see also Reproductive biology and autecology section). From observations made on the Rio Grande and Carson national forests (Burt personal communication 2002, Long personal communication 2002), it is likely that patches of *A. ripleyi* roots lie essentially dormant under canopy cover and sprout when suitable conditions recur. For example, within a “couple of weeks” of a burn on the Carson National Forest, stems of *A. ripleyi* were observed in areas where no plants were documented in the past (Long personal communication 2002). These *A. ripleyi* stems were likely from pre-existing root stocks because precipitation appeared to be inadequate for seed germination and no other annual species were observed in the burn areas. Although roots appear to undergo dormancy for extended periods, direct evidence is only available to support a dormancy period of two years. Plants tagged in 1996 did not reappear in 1997 but did come up in 1998 despite there being a high amount of moisture in 1997 (Burt 1998). Species having organs that experience prolonged dormancy are not unusual amongst many genera of geophyte vascular plants (Lesica and Steele 1994).

Lesica (1995) used stage-based transition matrix models and elasticity analysis to elucidate the demography and effect of herbivory on *Astragalus scaphoides*, which is another long-lived, tap-rooted perennial. His results are likely directly relevant to *A. ripleyi*. Obviously studies on *A. scaphoides* are no substitute for direct studies on *A. ripleyi*, but these studies support the conclusions deduced and outlined in the previous paragraph. Like *A. ripleyi*, *A. scaphoides* exists as dormant rootstocks, small non-reproductive plants, large non-reproductive plants, and reproductive plants. Also like *A. ripleyi*, it suffers from inflorescence predation by insects and livestock and from insect seed predation. It suffers losses of predispersal fecundity (total number of immature fruits) averaging 50 percent (for comparison see Reproductive biology and autecology section). Elasticity analysis revealed that population growth continued in spite of relatively small contributions by recruitment compared to growth and survival of non-reproductive plants and that the species in total depends little on reproduction and recruitment (Lesica 1995).

Burt (1999) reported a correlation between precipitation and number of stems observed at each site. Precipitation between October of the previous year and August was 5.56 inches in 1996, 8.62 inches in 1997, and

6.63 inches in 1998. In April 1998, a particularly heavy snowfall was reported (Burt 1999). The number of stems was used as a measure of population size. There were fewer stems at all six study sites in 1996 and at five of the six study sites in 1998 than in 1997 (**Table 4** - values are estimates taken from a graph in an unpublished paper by Burt 1999). One site had approximately the same number of stems in 1997 and 1998, and all sites in 1998 had more stems than in 1996. A simple ratio of the number of stems between years was used as an estimate of the change in the size of the population (**Table 4**). That is, the ratio of the number of stems in one year to the number of stems in a previous year provided a numerical measure of the difference in size of the population. If the ratio was greater than 1, the population had grown between years; if it was less than 1, it had decreased. This measure of population size (number of stems) is subject to error because some individuals may have had single stems in some years but multiple stems in others. Also, because of the prolonged dormancy of the rootstock, the number of stems does not accurately reflect the size of the true population in any single year. The true population is the number of individual roots belowground. Between 1 and 23 percent of individuals of *Astragalus scaphoides* remained dormant in a single year (Lesica and Steele 1994). Therefore, the ratio of stems between years may more accurately reflect the change in aboveground productivity of the population. This, in itself, is an interesting parameter, but many years of observations must thus be made to determine the stability of a population.

The observations of Burt (1999) indicated that an overall increase in stem number occurred between 1996 and 1997 and between 1996 and 1998, but a decrease in stem number occurred between 1997 and 1998. This variation emphasizes the importance of multiple year monitoring. Interestingly, although precipitation is often ascribed to explain variation in population size, as measured by aboveground stem number, the precipitation in 1996 and 1998 did not appear substantially different. It may be that the heavy snowfall in April 1998 was particularly important in stimulating stem growth. This observation suggests that it is not only total precipitation but also when precipitation occurs, and perhaps the form in which it occurs, that is significant. Another factor to consider in interpreting the trend is that precipitation records are for the general region and local precipitation levels may differ. Other internal or environmental triggers that could affect dormancy have not been investigated.

It should be noted that the data available for *Astragalus ripleyi* does not permit calculation of a

Table 4. Numbers of stems and precipitation at five sites in the Rio Grande National Forest. Values are estimates taken from a graph in an unpublished paper (Burt 1999).

Year	1996	1997	1998	1997/1996 Stem Ratio ¹	1998/1997 Stem Ratio	1998/1996 Stem Ratio
Precipitation						
	5.56 inches	8.63 inches	6.63 inches			
Number of stems						
Site 1	~ 275	~ 490	~ 420	1.78	0.86	1.53
Site 2	~ 250	~ 580	~ 580	2.32	1	2.32
Site 3	~ 160	~ 410	~ 430	2.56	1.05	2.69
Site 4	~ 80	~ 170	~ 95	2.13	0.56	1.19
Site 5	~ 95	~ 420	~ 250	4.42	0.6	2.63

¹Stem ratio = the number of stems in one year divided by the number of stems in a previous year. Stem ratio provides a numerical value of the increase or decrease in the number of stems from one year to the next. If the ratio is greater than 1 the number has increased between years and if less than one it has decreased.

rigorously calculated equilibrium growth rate (λ) that integrates the effects of survival, growth, and fecundity of the different life history stages into a single parameter (Caswell 1989, Silvertown et al. 1993). The value λ provides a measure of population stability as well as growth rate (Lesica and Shelly 1995). Demographic studies that incorporate stage-structured transition models and elasticity analyses are useful when comparing the importance of different life stages, which may change depending upon the conditions experienced by different populations. Although results must be interpreted with care, such studies also assist in evaluating the vulnerability of the different life stages to management practices or different environmental conditions (Mills et al. 1999). Elasticity analysis of matrix projection models can indicate how the importance of specific life strategies, such as recruitment or adult survivorship, may vary among populations or over time. An example is one where it was found that adult survivorship contributed most to population growth of a perennial species at site A, while annual fecundity and recruitment were more important at sites B and C (Lesica and Shelly 1995). In this case, managers may be most concerned with protecting the adult plants at site A, while being most concerned with protecting seed set and recruitment at the other sites. An example of subsequent management recommendations may be to prohibit off-road vehicle traffic at site A and to restrict livestock grazing to winter at sites B and C.

Even though *Astragalus ripleyi* is not rhizomatous, the multiple stems that appear to be unrelated aboveground can actually belong to the same plant (Burt personal communication 2002). This condition will lead to an overestimation in the potential for genetic diversity within a population and may confound population

viability analysis (Menges 1991). No analyses of population viability are available. As well as threats associated, directly or indirectly, with human activities there are uncertainties that can only be addressed by increasing both number of populations and their size. These uncertainties that are typically addressed in population viability analysis include elements of environmental stochasticity, demographic stochasticity, genetic stochasticity, and natural catastrophes (Shaffer 1981). The term “stochasticity” is replaced by “uncertainty” in the following discussion (Frankel et al. 1995). The influences of the different types of uncertainties to *A. ripleyi* may only be commented upon with little supporting quantitative data.

Environmental uncertainty lies in random, unpredictable changes in weather patterns or in biotic members of the community (Frankel et al. 1995). Demographic uncertainty relates to the random variation in survival and fecundity of individuals within a fixed population. Genetic uncertainties are associated with random changes, such as inbreeding and founder effects, in the genetic structure of populations. Specific environmental uncertainties that likely affect survival and reproductive success of *Astragalus ripleyi* include variation in precipitation, soil erosive forces, and variable populations of arthropods (pollinators, herbivores, granivores), rodents, and other wildlife (see Community ecology and Threats sections).

No studies have been undertaken to determine the genetic structure of either range-wide or local populations. Locally endemic species of *Astragalus* tend to exhibit reduced levels of polymorphism (Karron 1991) that may imply a reduced robustness against environmental uncertainty. However, while rare

species can have statistically less genetic variation than their widespread congeners, there is a large range in values (Gitzendanner and Soltis 2000). In fact, some rare species exhibit levels of diversity equal to, or exceeding, that of widespread congeners (Gitzendanner and Soltis 2000). Without genetic evaluation, it is difficult if not impossible to predict the genetic vulnerability of *A. ripleyi*. Even so, some comments on the subject are appropriate.

Astragalus ripleyi occurs either individually or in clusters that may be comprised of less than 10 to several hundred individuals. Its sprouting habit and the observed clustering of stems within an area of seemingly equivalent habitat indicate that ramets may make up a significant fraction of the group occupying a small area. It is important to consider that it is not clear as to what constitutes a population of *A. ripleyi*. Do 325 individuals distributed in patches over 60 acres interact and comprise a population, or are the patches genetically isolated and adapted to microhabitat conditions? The genetic isolation of an occurrence of “less than 6 stems observed after a days hiking” is unknown. Where occurrences of this species are small, perhaps less than 50 individuals, demographic uncertainty may be important (Pollard 1966, Keiding 1975). Chance events independent of the environment may affect the reproductive success and survival of individuals that, in very small populations, have a proportionally more important influence on survival of the whole population. It is important to understand the associations between relatively small and isolated occurrences.

Spatially disjunct groups may have high levels of dispersal and gene flow between them. Osborne et al. (1999) tracked individual bumblebees using harmonic radar and recorded that most bees regularly fly over 200 m (range 70 to 631 m) from the nest to forage even when ostensibly plentiful food was available nearby. Honeybees can regularly forage 2 km away from their hive (Ramsey et al. 1999). This suggests that occurrences within at least 200 m, and most likely further, are exchanging genetic material to some degree, and at least in some years. As discussed, *Astragalus ripleyi* appears to be bee-pollinated, and thus outcrossing among adjacent occurrences is likely. However, because bees are density-dependent foragers, it is unclear how much genetic exchange is between, rather than within, small patches of plants, especially in conditions of low flower production such as drought or under high levels of herbivory when it may be likely that there are other species of flowering plants in greater abundance between occurrences (see Reproductive biology and autecology section). Even though there may

be considerable genetic variation between populations, if there is little genetic exchange among small occurrences there might be little variation, increasing vulnerability to genetic uncertainty, within populations. Loss of heterozygosity is strongly correlated with a substantial decrease in population fitness (Reed and Frankham 2003).

Community ecology

Astragalus ripleyi is very palatable to all herbivores and appears to be particularly targeted by arthropods and rodents (Burt 1999, Burt personal communication 2002). In some years insect herbivory significantly reduces the aerial parts of the plant, but in most years mammalian herbivores cause the most impact (Burt 1996, 1999). Arthropods that have been identified on *A. ripleyi* include aphids that swarm on flowering stems, and treehoppers, specifically *Campylenchia curvata*, that attack the stems and are apparently defended by ants that are often observed on plants (Burt 1999). Carpenter ant holes are frequently found at the base of large plants (Burt 1999). Stems with evident insect damage are included amongst herbarium specimens (personal observation at Rocky Mountain Herbarium). Rodents eat the leaflets and upper stems and will also cache fruits in small piles near plants (Burt 1999). The long-term effects of fluctuating rodent population size, such as has been documented in New Mexico over the last decade, are unknown. Cattle and other large mammals such as elk and deer eat the inflorescence and upper stems off the plants. Sheep may be particularly damaging herbivores (Naumann 1990, Lightfoot 1995). Sheep may also interact negatively with the bee pollinators of *A. ripleyi*. Sugden (1985) reported that sheep grazing in the habitat of *A. monoensis*, another perennial endemic species, endangered bee pollinators by destroying potential and existing nest sites and removing food resources. Although *A. ripleyi* depends primarily on its long-lived root system for survival, indirect impacts, such as a constraint on potential pollinators, are important to consider.

No fungal or microbial diseases have been reported. Spores of the fungus, *Helminthosporium carbonum*, elicit production of maackiain, an isoflavan phytoalexin, in *Astragalus ripleyi* leaves (Martin 1990, Martin personal communication 2002). Phytoalexins are understood to be a form of defense against fungal diseases.

Evidence of rhizobium or mycorrhizal associations with the root system has not been

documented. Rhizobial association is likely since *Astragalus lonchocarpus*, a closely related species, was reported to be nodulated (Allen and Allen 1981). This association with nitrogen-fixing bacteria would provide an important source of nitrogen to the soil, as well as to *A. ripleyi*.

The habitat of *Astragalus ripleyi*, namely open savannahs and shrublands, open canopy ponderosa pine forests, and edges of closed canopy forests and woodlands, suggests that it is a mid-successional species. It rarely occurs in recently disturbed sites, such as road cuts, but it is frequently found in areas that have had disturbance, such as fire, recorded within a decade. It has been hypothesized that *A. ripleyi* benefits from an intermediate disturbance regime, and in pre-settlement times it may have occupied habitats that were periodically opened up by fire (Naumann 1990, Lightfoot 1995).

Astragalus ripleyi appears adapted to a landscape with periodic fire. In 1996, a fire started in the Carson National Forest. Within 24 hours approximately 8,000 acres had burned; this represented about 90 percent of the total burn area and contained the majority of *A. ripleyi* occupied habitat. Although no precipitation occurred until July, within weeks of the burn populations of *A. ripleyi* were observed in areas where no plants had been observed before (Long personal communication 2002). These were sturdy individuals that apparently came from the root systems that had lain dormant in the ground. Approximately eight new populations were observed, many in previously open, shrubby meadowland. The occurrence sizes ranged from less than ten to over 50 individual stems per site (Long personal communication 2002). One general comment that may be made on observing plants after fire is that individuals may be easier to distinguish at that time. Prior to fire, herbaceous cover may obscure sparsely distributed individual stems.

In addition, the long-term effects of fire should not be judged based on a few observations. There is no information concerning the effects of the intensity, frequency, extent, and season of fire. Severe drought was experienced for two to three years in the Questa Ranger District prior to the fire in May 1996, and no precipitation occurred until several months after the fire. Although soil is typically a good insulator, the prior drought may have been advantageous for *A. ripleyi*, which sprouts from buried roots, because moist soil often reaches a higher peak temperature and reaches it more rapidly than air-dry soil at a given depth (Whelan 1997). Therefore, cooler soil temperatures during the

fire may have benefited *A. ripleyi* establishment. The drought may also have favored *A. ripleyi* because post-fire climate is more important for obligate seeders than for “sprouters”, such as *A. ripleyi* (Whelan 1997). The season of the fire may have been additionally fortuitous because greater increases in the growth of forbs have been noted after May fires than after fires in other seasons (Whelan 1997). Fire frequency may also be an important factor in population persistence, but the capacity of *A. ripleyi* for repeated recovery is not clear. Generally, fires that are relatively hot and produce a medium level of disturbance are understood to favor a rhizome regeneration system (Oliver and Larson 1996). Rapid colonization after fire during a drought suggests that *A. ripleyi* is tolerant of drought and worthy of a stress-tolerator classification (Grime et al. 1988).

Even though reducing canopy cover is currently believed to be most important, *Astragalus ripleyi* may respond to other consequences of fire. Some other effects of fire include removing litter, eliminating or reducing competition from other species, and changing the soil nutrient and microbial environment (Oliver and Larson 1996, Whelan 1997). Curtis and Partch (1950) found that clipping *Andropogon* swards produced increases in density and height of flowering stems virtually equivalent to those occurring after burning. Granted *Andropogon* is a grass, but the impact of litter on *A. ripleyi* has not been evaluated and should be considered. Although a consequence of fire is an increase in nutrients in the soil, nitrogen can be also be lost by volatilization. Therefore, a species that fixes nitrogen may initially have an advantage. It is unknown as to whether a symbiont of *A. ripleyi* fixes nitrogen but, as mentioned above, a closely related species has been reported to be associated with rhizobium.

The association between *Astragalus ripleyi* and shrubs such as *Artemisia tridentata*, *Ribes* spp., and *Symphoricarpos* spp., is well documented (Romero 1992, Burt 1999). The association may be due to advantageous microsite characteristics for germination and seedling development, or the shrubs may provide refugia from large mammal herbivory (see Habitat section). *Astragalus ripleyi* appears to be at risk from interspecific competition with herbaceous plants. Some aggressive weedy species, such as *Melilotus officinalis*, are perceived to be particularly strong and detrimental competitors (Naumann 1990, Burt 1999, Long personal communication 2002). In addition, observations have been made that suggest *A. ripleyi* population size is also influenced by native, non-aggressive species (Long personal communication 2002). The numbers of individuals at sites observed immediately after the fire

declined during years succeeding a fire in the Carson National Forest. For example, at one site where over 50 individuals were counted in 1996, the year after the fire, only 20 individuals were counted in 2001. Although environmental conditions may have contributed to the difference, the decline was speculated, at least in part, because *A. ripleyi* was out-competed by the abundance of grasses and forbs that grew up over the months and years following the burn (Long personal communication 2002). This observation may also reflect the year-to-year variability in stem number that is a function of prolonged dormancy of the rootstock (see Demography and Population monitoring sections). Trees may also be competitors, primarily for light, and canopy closure is understood to reduce population size (Lightfoot 1995). However, it may be that, although canopy closure reduces stem number, the roots remain dormant for long periods of time and exploit disturbances that reduce or eliminate canopy.

Pollinators are important resources aiding gene flow among occurrences. Pollinators, as a resource, were discussed in the Reproductive biology and autecology section. Although not documented, there may be other “resource” arthropods, essentially predators, which provide a biological control to the observed insect herbivores. Interactions between arthropods and their relationship to specific plant species are generally not well documented.

An envirogram is a graphic representation of the components that influence the condition of a species and reflects its chance of reproduction and survival. Envirograms have been used extensively to describe the conditions of animals but may also be applied to describe the condition of plant species (Andrewartha and Birch 1984). Those components that directly impact *Astragalus ripleyi* make up the centrum and the indirectly acting components comprise the web (**Figure 7** and **Figure 8**). Unfortunately much of the information to make a comprehensive envirogram for *A. ripleyi* is unavailable. These envirograms are constructed to outline some of the resources (**Figure 7**) and malentities (**Figure 8**) known to directly impact the species and also include some more speculative factors that can be tested in the field by observation or management manipulation. Dashed boxes indicate likely, but not proven, resources or malentities. Malentities are also discussed in the Threats section immediately following this section.

CONSERVATION

Threats

Threats and potential threats that have been identified are related to herbivory, human recreation, interspecific plant species competition, and global climate change. Some of these factors were also alluded to in the Community ecology section. All of these threats are applicable to at least some populations on land managed by USFS Region 2. The extent to which populations will be threatened will depend on prevailing recreational uses and the status of grazing allotments. Although there is little on a local level that can be done to avoid the consequences of the threat of global warming, control of pressures that contribute to stress may to some extent mitigate the impacts in the short term. Each threat, or potential threat, is discussed briefly in the following paragraphs.

Astragalus ripleyi is very palatable to many herbivores. Arthropods, rodents, wildlife such as elk, deer, and rabbits, and livestock such as cows, sheep, and goats all browse upon it. Livestock grazing has been suggested as being a significant threat due to the obvious palatability of the stems and the observed grazing activity at *A. ripleyi* sites on both the Carson and Rio Grande national forests (Naumann 1990, Lightfoot 1995). Herbivores often utilize plants during flowering before the plant goes into seed production, and aboveground vegetative losses can be as much as 70 percent (Naumann 1990, Romero 1992). Burt (1999) did not believe cattle particularly targeted *A. ripleyi* but browsed on them coincidentally. Because of the considerable size of cattle and elk, these large mammals have a substantial impact on any plants that they eat or inadvertently trample. The frequent observation that *A. ripleyi* grows in the center of a shrub where it is protected from large herbivores has been cited as evidence of either livestock or elk grazing pressures (Naumann 1990, Lightfoot 1995, Burt 1997, O’Kane personal communication 2002).

Herbivory is likely to cause a decline in seed production because *Astragalus ripleyi* does not compensate for vegetative loss with new growth but, presumably, puts available resources into its root system for growth in another year (Burt 1999). Since reproduction and recruitment are likely not paramount to the survival of this long-lived perennial, populations

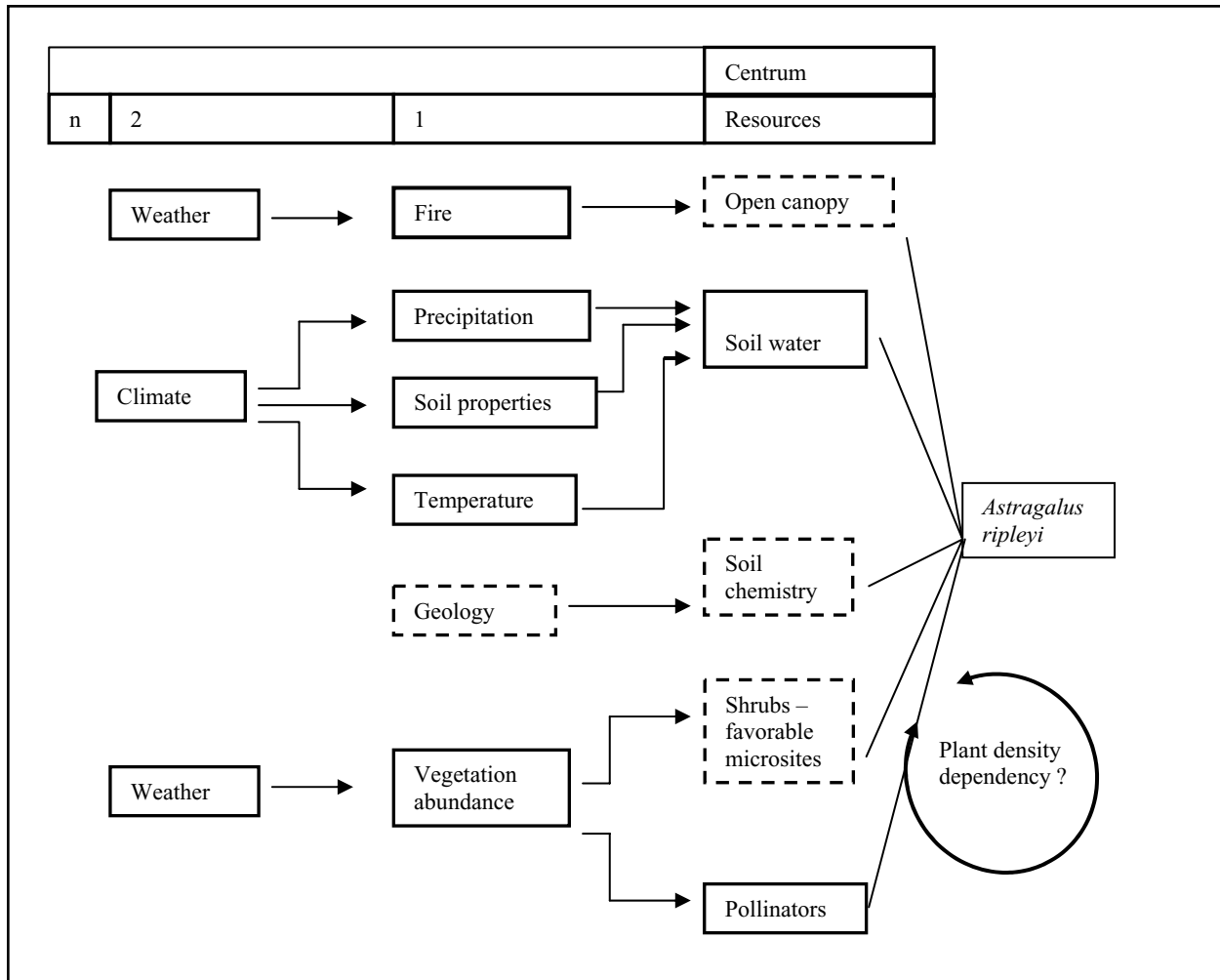


Figure 7. Envirogram of resources of *Astragalus ripleyi*.

may persist in the presence of seasonal-rotational livestock grazing (see Demography and Community ecology sections). Studies on a similar species, *A. scaphoides*, indicated that high stocking rates during periods of growth, or other management practices that lower growth and survival of individuals, will have a much more detrimental effect than just seed loss on population viability (Lesica 1995). The studies also showed that while repeated spring grazing is detrimental, rotation-grazing systems in which spring grazing occurs only one in three years appear to be compatible with the long-term persistence of *A. scaphoides* populations (Lesica 1995). There is no information on the palatability of *A. ripleyi* to bighorn sheep, but it is palatable to domestic sheep, which eat plants down to the ground and show selectivity (Strasia et al. 1970, Bonham 1972). Because of these habits that are peculiar to domestic sheep, they may be more detrimental to long-term survival than either cattle or elk (Braun 1988, Lightfoot 1995). With no

grazing pressure, plants grow taller than 3 feet (Weber 1952). Size of plants indicates a competitive advantage (Menges 1991), and size rather than age has been reported to be a better predictor of success (Frankel et al. 1995). Grazing and other herbivore activity may reduce that competitive advantage and contribute to the decline observed by Long (personal communication 2002) as the sites after fire became re-colonized by native plants. One report has indicated that arthropod herbivory was more of a threat than livestock and wildlife herbivory, but this was only based on one year of data (Burt 1997). Subsequent studies indicated that all herbivory, including that caused by rodents, could be equally detrimental and that environmental conditions were important in determining the degree of impact on a population (Burt 1999).

There is significant seed predation by insects (Coles 1996, Burt 1997), but in light of Lesica's work (1995) on *Astragalus scaphoides* relatively high levels

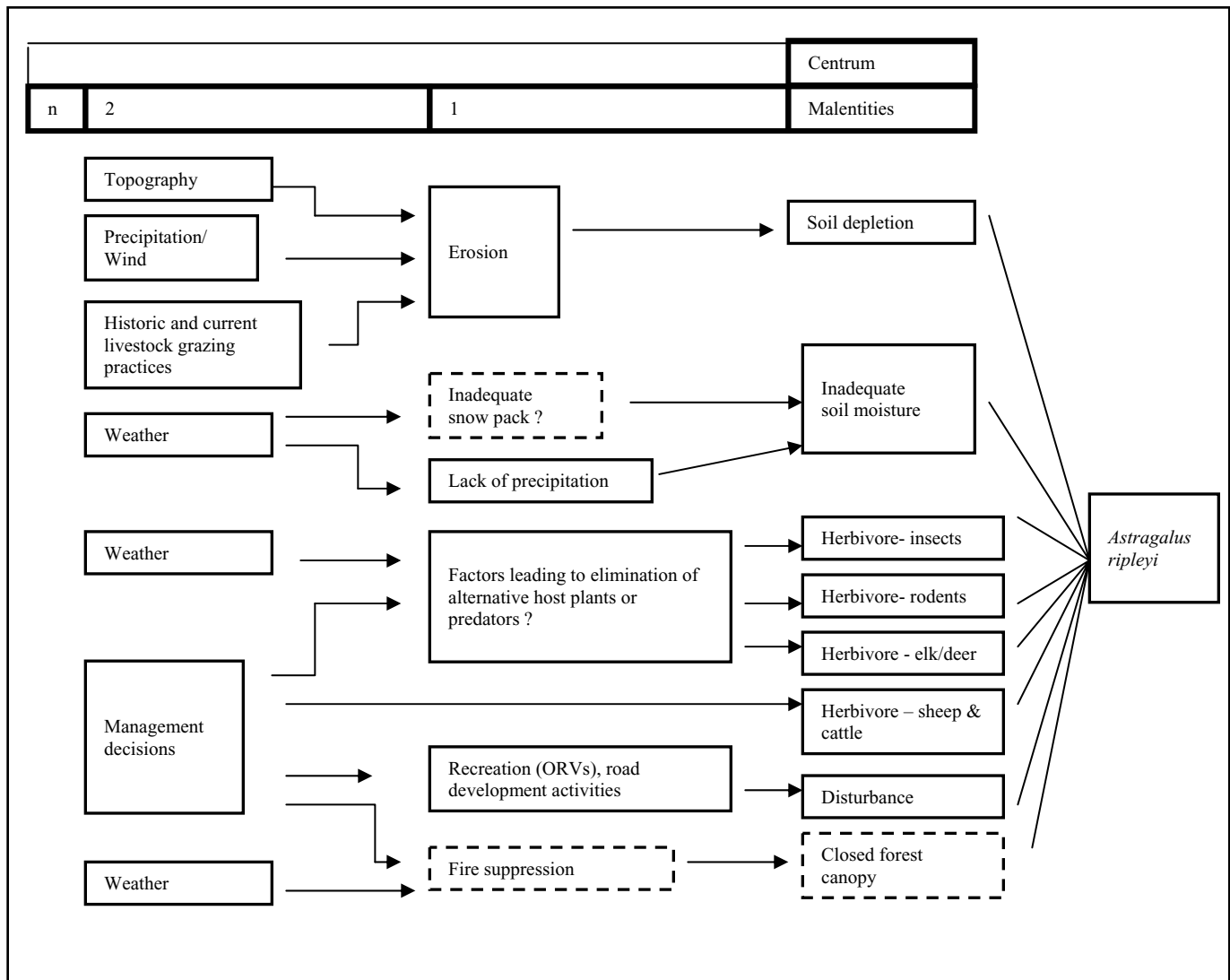


Figure 8. Envirogram of malentities of *Astragalus ripleyi*.

are likely tolerated with no ill effects to the population. In addition, seed predation by arthropods is not necessarily bad at levels under which the species has evolved and may be important to long term species sustainability. In some cases it may have had an important influence on population dynamics and diversity within the genus *Astragalus* (Green and Palmbald 1975, Mancuso and Moseley 1993).

The potential for interaction between the consequences of fire and herbivory has not been examined for *Astragalus ripleyi*. A particularly interesting interaction was reported for a woodland community in Australia. Leigh and Holgate (1979) found the mortality rate for palatable species on sites that experienced both burning and post-fire grazing was double the mortality rate for sites that experienced either

factor alone. In addition, mortality on burned-only or grazed-only plots was not much different than on control plots. An indirect consequence of fire that may negatively impact a palatable species is that herbivores tend to congregate on patches where vegetation has burned (Whelan 1997). Typically, re-growing shoots are protein rich after a fire and attract herbivorous insects and mammals.

The importance of the root for long-term persistence suggests that soil erosion and activities disturbing the top few centimeters of the ground surface, such as off-road-vehicle recreation, may be particularly detrimental. Active soil erosion is currently threatening a population in the Rio Grande National Forest (Burt personal communication 2002). A small population has been reported growing in a small arroyo

(Tonne and Sivinski 2000), and it is likely that such populations are especially vulnerable to erosive forces such as flash flooding.

Road building and road widening activities may also have had impacts on some occurrences. *Astragalus ripleyi* was reported to be common along Highway 44 within the Rio Grande National Forest (Weber 1955), but few plants have been observed within the last decade (Burt personal communication 2002, Erhard personal communication 2002). In Colorado, only federally listed species are protected on rights-of-way managed by the Department of Transportation (Powell personal communication 2002). In New Mexico, plants have been observed in areas with roadside construction in the Carson National Forest (Braun 1988, Romero personal communication 2002).

Road maintenance practices are not known to have directly impacted *Astragalus ripleyi*. Mowing is unlikely to have any short-term impacts. Yearly mowing during the growing season may eliminate viable seed production and so may have detrimental consequences over the long term. The impacts of herbicide use have not been evaluated. Sites with potential habitat that had been treated in the past with the herbicide tebuthiuron were surveyed, and no plants were found at any of the sites (Braun 1988). However, it was not known if plants were there before chemical treatment, so no conclusions can be made with respect to persistence after treatment. Some populations that occur in sagebrush associations may be periodically impacted by brush control operations (Sivinski and Lightfoot 1995).

Agricultural conversion has likely impacted some populations in the past and may in the future. One population has been found in a horse pasture that, in the past, had been plowed and seeded with *Agropyron cristatum* (Braun 1988). The date when the plowing happened and the exact procedure used is uncertain, and it is unknown whether *Astragalus ripleyi* was present before the disturbance. It is likely that the pasture was once sagebrush rangeland that was disk plowed to leave stubble and then the seed drilled in one half- to one-inch deep (Martin et al. 1976). If this was the case, the soil disturbance might have been uneven and relatively superficial, and some existing root systems remained. Unfortunately this is merely speculation, and the significance of this observation cannot be applied to situations that experience permanent agriculture conversion.

Invasive weed species may be another significant threat (see Community ecology section). Interspecific competition is a problem (Naumann 1990, Long personal communication 2001). Some populations on the Carson National Forest have declined in size, or have been eliminated, at sites that have been invaded by *Melilotus officinalis* and *Trifolium repens* (Long personal communication 2002). Because there has not been formal monitoring, numerical values of the impact are not available. The impact of aggressive, invasive non-native plant species on *Astragalus ripleyi* has not been documented. *Cirsium arvense* (Canada thistle) grows near known occurrences in the La Jara Canyon area (Occurrences 26, 27, and 28 in **Table 1**), but it is not known if the species grow together. Since *A. ripleyi* is generally non-competitive, it is likely that such aggressive species would have a negative impact on population size and vigor.

In one scenario of global climate change, New Mexico will experience long droughts, punctuated by heavy rains, and a warming trend that will expand grassland at the expense of savanna woodland (U.S. Environmental Protection Agency 1997, U.S. Environmental Protection Agency 1998). Some modification of savanna woodland may be tolerated, although it would depend upon the species involved (see sections on Habitat and Community ecology). Invasion by annual grasses that would substantially alter soil properties and the fire regime may be detrimental, whereas shrubby, native grassland may provide suitable habitat. It is not clear how *Astragalus ripleyi* would tolerate warmer temperatures, but it appears that its life cycle is well adapted to endure long droughts and exploit times of abundant precipitation, as long as flooding or severe soil erosion posed no threat. However, the same manifestations of climate change may also have some indirect effects. Long droughts punctuated by heavy rains can decrease the predators (owls, snakes, and coyotes) of species such as rodents. An exploding rodent population may have a significant negative impact on *A. ripleyi*. Similarly, the effects of perturbations on arthropod populations cannot be predicted.

Malentities are outlined in **Figure 8**. In summary, on the Rio Grand National Forest most of the threats outlined above are a concern. Herbivory by livestock and wildlife is a potential threat because the levels that can be sustainability tolerated are not known. Fire suppression may be of concern because *Astragalus ripleyi* appears to be a mid-successional species that

is likely excluded by mature tree canopy closure (Lightfoot 1995). This observation suggests that logging and firewood cutting *per se* are not harmful, because they are likely to open up potential habitat for *A. ripleyi*. However, the ground disturbance associated with such activities may have very deleterious consequences.

Conservation Status of the Species in Region 2

Many populations known from earlier observations are still extant in Region 2. However, evidence exists that some populations have declined in size or have been extirpated, for example along the roadside of Highway 44 (Colorado Natural Heritage Program 2002, Erhard personal communication 2002, Sivinski personal communication 2001). There appears to be adequate potential habitat for this species under current USFS management practices (USDA Forest Service 2001), although our ignorance of reasons why it has a very patchy spatial distribution indicates that we may overestimate “potential habitat.” Rigorous analyses of habitat requirements have not been done (see Distribution and abundance section).

Seedling recruitment appears to be a relatively uncommon event, and the establishment of populations through seed dispersal may be infrequent. Seed of *Astragalus ripleyi* is not currently being saved. Considering that there appear to be adequate extant populations for continued sustainability, monitoring and inventory are likely more cost and time effective programs than re-seeding or saving seed at the present time. Successful seed collection and storage is not an easy proposition and cannot be undertaken lightly. National native seed collection efforts are currently being undertaken. For example, Seeds of Success is an interagency program coordinated through the Plant Conservation Alliance that supports and organizes seed collection of native plant populations to increase the number of species and the amount of native seed that is available for use in stabilizing, rehabilitating, and restoring lands in the United States. However, because *A. ripleyi* is a substrate and regional endemic, this species is unlikely to be an appropriate species to include as a target in the Seeds for Success Program. In the future when there is a suitable repository, the seed of all endemic and rare species, including *A. ripleyi*, should be considered for deposit in a national storage facility.

Land use practices that lead to soil erosion or disturbance of the long-lived root system are likely to have a negative impact on population size and longevity.

The aerial parts of this species are particularly palatable to a wide range of herbivores. The levels of herbivory and disturbance that permit sustainable populations are unknown. To lessen the potential impact of livestock grazing, the Rio Grande National Forest plans to avoid season-long grazing and to incorporate rotation-grazing schemes within *Astragalus ripleyi* habitat, thus insuring that this species is not grazed at the same time of year every year (USDA Forest Service 2002). The consequences of these practices can only be evaluated through long-term monitoring (see Demography and Tools and practices sections).

Management of the Species in Region 2

Implications and potential conservation elements

Fire suppression has been practiced within the range of *Astragalus ripleyi*. Past and current land use practices rangewide and within Region 2 include grazing, tree planting, logging, firewood cutting, stand thinning, controlled burning, enhancement for big game habitat, road building and maintenance, recreation including off-road vehicle activities, and agricultural conversion. It is likely that all these activities will continue to occur in the future.

It has been suggested that long-term fire suppression has influenced the distribution and abundance of this species (Lightfoot 1995). The degree to which long-term fire suppression has adversely impacted the range and abundance of this species largely depends upon the longevity of the root systems, the frequency of seedling recruitment, and seed dispersal patterns. Current evidence suggests seedling recruitment is infrequent and seeds have a restricted dispersal pattern. Both of these characteristics lead to vulnerability to the consequences of fire suppression (see Reproductive biology and autecology section). However, there is no direct evidence that fire suppression has impacted the distribution or abundance of this taxon.

An amendment was made to the 1996 “Land and Resource Management Plan for the Rio Grande National Forest” in 1999 (USDA Forest Service 1999). A Special Interest Area established to protect *Astragalus ripleyi* was reduced in size because it was thought that *A. ripleyi* did not typically occur above 9,200 feet. Plants extend to 9,430 feet in this region and specifically have been found within the described geographic coordinates of the Rio Grande National Forest at 9,300 feet. The consequences of the

change in land use designation are not documented. Observations on occurrences before and after a change in management policy has been implemented are useful in evaluating alternate management strategies for other areas. Mitigation recommendations for the area were to “avoid timber harvest and prescribed fire in potential *A. ripleyi* [Ripley’s milkvetch] habitat.” It was not stated whether lightning strikes should be allowed to burn.

Logging, firewood cutting, and thinning in the absence of significant soil disturbance may benefit populations, although more information is required before it can be recommended as a beneficial management strategy. One practice implemented on land managed by the State of Colorado limits logging to the winter months to minimize soil disturbance (Page personal communication 2002). When considering appropriate management practices, one problem is in identifying occurrences when environmental conditions, for example drought, are unsuitable for sprouting (see Habitat section). The population size aboveground and the number of occurrences are variable. *Astragalus ripleyi* is locally common in some years but very rare in others (see Distribution and abundance section). Although a critical factor is understood to be sufficient moisture, there may be internal dormancy factors or additional environmental triggers that affect stem number (see Demography section). Once an occurrence is discovered, the absence of plant stems over one or two years does not indicate that the occurrence has been extirpated.

The scale, rather than the act *per se*, of herbivory over consecutive years appears most important. *Astragalus ripleyi* is palatable to a wide range of fauna; arthropods, rodents, deer, and livestock all seem to eat the vegetation, flowers, and fruits (see Threats section). This species appears to tolerate some herbivory, but it is reasonable to suppose there may be cumulative effects and interactions both over the duration of the exposure and with respect to the diversity of animals that feed on this species. The dormant root systems seem well-adapted to persist with a range of herbivory. However, the level of use that is sustainable has not been determined. Rotation of pastures and a rest period for the species seems to be beneficial, but the periodicity of rotation favorable to this species is not known. Activities that substantially disturb the soil and interfere with the root system may be detrimental to this species (see Demography section). Soil erosion poses a serious threat, especially at some occurrences on the Rio Grande National Forest, and land management practices that minimize soil erosion have been recommended (Naumann 1990, Burt 1999). The Rio Grande National

Forest plans to avoid season-long grazing and to incorporate rotation-grazing schemes so that *A. ripleyi* species is not grazed at the same time of year every year (USDA Forest Service 2002).

The composition of seed mix used for reseeding disturbed sites in the past may have had an adverse impact on some populations, as evidence suggests that some persistent species out-compete *Astragalus ripleyi* (Nauman 1990, Burt personal communication 2002, Long personal communication 2002). A mitigation recommendation on one of the ranger districts of the Carson National Forest is that after disturbance projects no seed of aggressive species, particularly *Melilotus officinalis* and *Trifolium repens* be allowed to be planted on or within windblow distance of known *A. ripleyi* sites (Long personal communication 2002).

When considering which populations to protect, it is important to remember that rare species often exhibit genetic differences between populations. Small populations may be genetically depauperate as a result of changes in gene frequencies due to inbreeding, or founder effects (Menges 1991), but the value of small populations should not be under-estimated. For example, alleles that were absent in larger populations were only found in a small population of *Astragalus osterhoutii* (Karron et al. 1988). Therefore, in order to conserve genetic variability, in the absence of genetic data, it is likely most important to conserve as many populations as possible in as large a geographic area as possible and understand that a “larger” population is not automatically “better.”

Apparently the results of three years of plot monitoring led to the decision by the Rio Grande National Forest to discontinue monitoring *Astragalus ripleyi* (USDA Forest Service 2002). Three years may be sufficient to achieve a useful short-term sample, but it is unlikely to have allowed critical evaluation of population stability or long-term trends (Lesica and Steele 1994). It may be useful to consider that Lesica and Steele (1994) estimated that “when dealing with plants that have prolonged dormancy, it will be necessary to conduct a study for seven years to obtain five years of accurate data.”

Tools and practices

Inventory and monitoring populations and habitat

Astragalus ripleyi occurs in adjacent areas of Region 3 and Region 2 of the USFS. On these lands

the total amount of survey and monitoring activity has been approximately equivalent during the last 15 years, although these activities have taken place during different time periods and in different ways. At some times monitoring has been emphasized, while at others inventory has been emphasized. Combined inventory and monitoring is the best way to ascertain the effects of both man-made and natural environmental perturbations on *A. ripleyi*. Monitoring studies on defined populations are very few. One study, initiated in 1996, established monitoring plots with and without grazing exclosures on the Rio Grande National Forest (Coles 1996, Burt 1999). These have provided worthwhile information, and further study building upon the data already collected would be very valuable in developing optimal management practices. Observations made before and after the fire of 1998 in the Questa District of USFS Region 3 have also been helpful in assessing *A. ripleyi*'s response to fire and some other aspects of its biology. More observations and studies would be very valuable because with only one set of circumstances it is not possible to predict a species general response to fire or other environmental perturbation (see Community ecology section).

In evaluating the data for this status assessment, it appears that much of the information that exists cannot be critically assessed because of the lack of detail and formal documentation. It is well-appreciated that time and financial limitations often prevent detailed data collection, filing, and databasing, but the importance of written documentation cannot be over-emphasized.

Species inventory. Relative to many plant species, there has been a considerable amount of occurrence data collected on this species. This is likely due to its designated status as a sensitive species by the BLM, the USFS, and the Colorado Natural Areas Program. Even so, distribution surveys have been sporadic and data collection methods inconsistent. Trends are particularly difficult to interpret because the number of stems observed in any year is variable. At any site, the number of stems and the area they occupy are important data to collect. This species can be difficult for casual observation because of its patchy distribution. However, attempts should be made to describe the spatial structure of an occurrence. In addition, because of its irregular distribution and the frequent observation that all potential habitat is not occupied, attempts to convert the numbers observed along a transect line, or in a small area, to individuals per acre (for example in Romero 1992) are subject to error (see Demography section). Before attempting extrapolation from transect or plot data, a much larger area should be briefly surveyed

and described to determine what an appropriate and representative conversion factor for the area is. It is likely that no accurate estimation can be made on the presence or abundance of the species outside of the surveyed area unless the definition of potential habitat has been critically assessed. The Carson National Forest plan to manage *Astragalus ripleyi* recommends that surveys be conducted during flowering and fruiting periods (USDA Forest Service 1989). Without using the key characteristic of flat pods, it is very difficult to reliably distinguish *A. lonchocarpus* from *A. ripleyi* in the field (U.S. Fish and Wildlife Service 1993, Burt personal communication 2002). *Astragalus ripleyi* has 11 to 21 leaflets, and the pods are laterally compressed. *Astragalus lonchocarpus* has 1 to 9 leaflets, and the pods are dorsiventrally compressed (see Non-technical description section). Therefore, surveys must always be conducted at an appropriate time of year, and in the case of *A. ripleyi* this is when the plant has fruits and preferably also flowers. Flowers are very useful, as their color helps easy detection of plants among other vegetation.

Habitat inventory. Habitat inventories have not been reported. Occupied habitat descriptions suggest that habitat requirements are broader than initially reported. It is not clear if the few "unusual habitat types" are examples of relic populations that tolerate habitat modification, extensions of the species into different habitats, or an indication that once the species was far more common and has generally undergone a restriction in habitat type. When targeted surveys are being performed, negative data, that is reporting that the species has not been found in an area, is often as valuable as reporting its presence (for example, Tonne and Sivinski 2000). However, such information is seldom available. Unfortunately, occupied habitat can only be determined, at maximum, during approximately half the year, from early spring when the shoots appear to late fall when individual plants die back to ground level and the above ground vegetation dries, breaks off, and usually gets blown away.

Population monitoring. As mentioned previously, there have been few monitoring studies of defined populations. Several hypotheses on how *Astragalus ripleyi* responds to management practices, for example its response to closed canopy (see Habitat section), have become accepted. However, they still need to be rigorously examined, and it is essential to monitor populations that will be impacted by a land use change, such as prescribed burns and logging. A current example is one outside of USFS Region 2 jurisdiction but on nearby land managed by the State of Colorado.

Logging is taking place in the area of a known population of *A. ripleyi*. With the information available, the land manager decided that logging activity must be performed during the winter months (Page personal communication 2002). If it is solely canopy opening that benefits populations, the prediction is that stem abundance will increase because soil disturbance should be minimal in winter and the elimination of ponderosa pine canopy should be beneficial (see Habitat section). However, precise knowledge of the condition and number of the plants prior to the disturbance is lacking. If such a site could be surveyed for several years before and several years after the disturbance, the information gained would be invaluable. Similarly, when prescribed burns take place it is constructive to survey the area in advance at an appropriate time of year to determine if populations are observed and then follow up with surveys or monitoring activities for several years subsequent to the burn. When setting up a monitoring study, it is critical to define the goals.

Permanent monitoring plots for *Astragalus ripleyi* have been established on the Rio Grande National Forest. The aim was to learn more about the transition probabilities associated with the life cycle and the effects of herbivory (Burt 1997, 1998, 1999). *Astragalus ripleyi* is a long-lived species, and populations are believed unlikely to be very spatially dynamic. Permanent plots are an excellent way to make demographic studies of such a species and to monitor individuals over the years to determine their fate. It is likely that many years of useful data will be collected using such a strategy. Lesica and Steele (1994) discussed the monitoring implications of prolonged dormancy in vascular plants such as that exhibited by *A. ripleyi*. Their results indicated that population estimates of plants with prolonged dormancy based on random sampling methods will often underestimate density. They concluded that establishing permanent monitoring plots with repeated measure analysis might be the most effective way to monitor changes in population density with a reduced risk of bias (Lesica and Steele 1994). Compared to species that do not have an organ of prolonged dormancy, demographic monitoring studies of species with prolonged dormancy require longer periods of time to obtain useful information (Lesica and Steele 1994).

However, if the goal is to monitor sub-samples to detect changes in a larger population over a long time period, such as observing the effects of changing canopy cover, permanent monitoring plots may run into problems associated with auto-correlation (Goldsmith 1991). If the size of the plot is too small or the establishment of new plots is not part of the original

scheme, when plants die and no replacement occurs within the plot it is impossible to know the significance of the change without studying a very large number of similar plots. Given the likely short distance of seed dispersal and that adult plants are understood to be long-lived, it is expected that patches of *Astragalus* plants would be persistent. However, this has not been confirmed. There may be a series of colonizations and local extirpations of patches. This circumstance needs to be differentiated from the natural temporal variation in the aboveground evidence of a population due to the considerable variation in the dormancy period of the rootstocks. Species occurring in drought-prone habitats may have relatively large proportions of dormant plants, and the dormant periods may be longer than two years (Lesica and Steele 1994). Therefore, it is important to monitor the areas between sub-populations because the population dynamics are not known and shifts in stands within a population need to be recognized. To minimize the problems associated with auto-correlation, monitoring protocols for species with a spatially aggregated, or patchy, distribution have been described by Elzinga et al. (1998) and Goldsmith (1991).

Habitat monitoring. Habitat monitoring for this species is premature because the exact conditions for its survival are not well defined. There have been no formal studies on habitat monitoring specifically for *Astragalus ripleyi*. Weed management programs and surveys for invasive species are valuable “habitat monitoring” strategies. It appears that a mosaic of successional stages, likely typical of pre-settlement times, throughout the range of *A. ripleyi* would be beneficial for the sustainability of this species (Naumann 1990, Lightfoot 1995).

Information Needs

There appears to be adequate information on this species’ distribution to develop a regional conservation strategy. The distribution of many occurrences has been documented (record repositories are at the Colorado Natural Heritage Program and the New Mexico Natural Heritage Program), and it appears that all state and federal management agencies are aware of the species’ presence. This situation suggests that an effective regional conservation plan could easily be developed. However, documented, formal protective management and/or monitoring strategies for land on which it occurs have not been established by the various land management agencies. Documented plans and strategies provide a guide and stable source of information that allows continuity during staff turnover.

The information available suggests that *Astragalus ripleyi* is a mid-successional species that relies on growth and longevity, rather than fecundity, for survival. It occupies open canopy savannah, woodland, and forest edge habitats, and appears to be eventually excluded as the tree canopy closes (Naumann 1990, Lightfoot 1995). These habitat requirements have been deduced from observations of current occupied habitat and observations after the 1996 fire in the Carson National Forest. With the information currently available, it is difficult to predict the effects of individual, or combinations of, threats such as multiple herbivore pressure, prolonged drought, successive fires, or amount of soil disturbance that it can tolerate. A long-term monitoring study would answer many questions for formulating appropriate management plans. Understanding the patch dynamics of this species by observing the way in which disturbed patches change over time is necessary. It is not known with certainty how *A. ripleyi* ‘colonizes’ patches such as those observed on the Carson National Forest after the 1996 spring fire. It is most likely that rootstocks were already in some areas and merely sprouted after fire (see Demography section). However, there is no information as to how long they must have been dormant in the soil. Understanding the dormancy characteristics and longevity of the roots of individuals is considered critical to assessing this species’ resiliency to management practices.

Seeds or spores of vascular and non-vascular species generally colonize patches of suitable habitat by moving in from surrounding communities via water, wind, or animal vectors. The rate at which a patch recovers after disturbance depends partly on the nature of the disturbance and partly on the source and relative abundance of colonizers. In the case of the Carson National Forest fire, the population size of *Astragalus ripleyi* generally declined in the years following the fire. This suggests that the population was suffering from competition with other patch colonizer species (Long personal communication 2002). It is interesting and important to determine the frequency with which *A. ripleyi* can truly “colonize” unoccupied areas opened up by disturbance. Depending upon factors including the longevity of the root systems, the frequency of seedling recruitment, and the true extent of the restricted dispersal of seeds (see Reproductive biology and autecology section), long-term fire suppression may have had a significant impact on the range and abundance of this species. However, this hypothesis needs to be confirmed. The seed bank size, the longevity of seed, and the rates of recruitment are unknown but appear secondary in importance relative to the established root

systems. There is no information as to the viability of transplanting or seeding *A. ripleyi* into an area.

A study on the genetic structure of populations at the northern and southern limits of its range would determine how homogenous the species is and provide information on the genetic vulnerability of *Astragalus ripleyi*. The relative importance of conserving different populations for maintaining genetic diversity is unknown. Generalizations and deductions based on studies of species other than *A. ripleyi* are subject to error.

One important reason to continue monitoring and studying this regional endemic species is its apparent resilience to many land use practices. If population trends begin to show a steady decline or contraction of range over several years, it may indicate that a fundamental problem is occurring with the ecology of a particular region. The plots established on the Rio Grande National Forest provide an excellent basis for a long-term monitoring program. Partnering with other agencies or institutions to include other areas within its restricted range would also be very valuable. A noteworthy observation is that *Astragalus ripleyi* invariably grows in areas where plant species diversity is high (Braun 1988). This long-lived perennial may be a “barometer” of changes in the ecosystem. Although it cannot be determined how its abundance and range has been affected over the last century, with the current understanding of its ecology and biology on which to build, it may be a valuable species to monitor in the future.

The most critical information needs are summarized thus:

- ❖ Define habitat requirements; confirm the hypothesized requirement for open canopy.
- ❖ Determine the dormancy characteristics and longevity of the roots.
- ❖ Determine the impacts of interspecific competition.
- ❖ Clarify the long-term impacts of disturbance, including firewood cutting and logging.
- ❖ Clarify the long-term impacts of fire and fire suppression.

❖ Clarify the long-term impacts of the different types of herbivory.

❖ Determine the genetic variability for *Astragalus ripleyi*.

DEFINITIONS

Congeners. Individuals of the same genus (in other contexts it may be a person, animal, or thing of the same kind or race).

Dorsiventral. On the plane running from the dorsal to the ventral side of a structure. (Harrington and Durrell 1979).

Geophyte. A land plant that survives an unfavorable period by means of an underground storage-organ (Allaby 1992)

Mesic. Moist or wet.

Phalanx. In North America the species in the genus *Astragalus* are divided into “phalanxes” (which can be thought of as “sub-genera”) that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

Rank. NatureServe and the Heritage Programs Ranking system (Internet site: <http://www.natureserve.org/explorer/granks.htm>). G3 indicates *Astragalus ripleyi* is “vulnerable globally either because it is very rare and local throughout its range, found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction or elimination. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals”. S2 indicates it is “imperiled in the nation or subnation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation or subnation. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000).” S3 indicates “vulnerable in the state either because the taxon is rare and uncommon or it is found in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 8,000 individuals.”

Rhizomatous. “Having the characters of a rhizome. A rhizome is any prostrate more or less elongated stem growing partly or completely beneath the surface of the ground; usually rooting at the nodes and becoming upturned at the apex.” (Harrington and Durrell 1979).

Section. In North America the species in the genus *Astragalus* are divided into “phalanxes” (which can be thought of as “sub-genera”) that in turn are divided into sections and sometimes further into sub-sections (Barneby 1964).

Stipe. The stalk between the pod body and the calyx.

COMMONLY USED SYNONYMS OF PLANT SPECIES

Commonly used synonyms of plant species (Kartesz 1994) mentioned in this report. The reference in parentheses refers to a flora in Region 2 in which the synonym is used:

Juniperus monosperma

Juniperus osteosperma

Juniperus scopulorum

Artemisia nova

Artemisia tridentata

Pentaphylloides floribunda

Rhus trilobata

Picradenia richardsonii

Linium lewisii

Agropyron trachycaulum

Agropyron smithii

Stipa hymenoides

Elymus elymoides

Sabina monosperma (Weber and Wittmann 2001)

Sabina osteosperma (Weber and Wittmann 2001)

Sabina scopulorum (Weber and Wittmann 2001)

Seriphidium novum (Weber and Wittmann 2001)

Seriphidium tridentatum (Weber and Wittmann 2001)

Potentilla fruticosa (Harrington 1964)

Rhus aromatica ssp. *trilobata* (Weber and Wittmann 2001)

Hymenoxys richardsonii (Dorn 2001)

Adenolinum lewisii (Weber and Wittmann 2001)

Elymus trachycaulus (Weber and Wittmann 2001)

Pascopyrum smithii (Weber and Wittmann 2001)

Oryzopsis hymenoides (Weber and Wittmann 2001)

Sitanion hystrix (Harrington 1964)

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